Sensory profiles and the effect of age, feeding regime and aging on quality of selected beef cuts

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Dissertation

M Consumer Science (Food management)

Study leader: Dr A.T. Viljoen

Co study leader: Dr P. E. Strydom

Co Study leader: Dr G. E. DuRand

January 2015

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by

ORATILE CHARMAIGNE SEHOOLE

Dissertation submitted in partially fulfilment of the requirement of the degree

Master in Consumer Science: (Food management)

in the

Faculty of Natural and Agricultural Sciences

Department of Consumer Science

University of Pretoria

Study leader: Dr A.T. Viljoen

Co study leader: Dr P. E. Strydom

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January 2015

Jeremiah 29:11

"For I know the plans I have for you," declares the Lord, "plans to prosper you and not to harm you, plans to give you hope and a future."

"Our deepest fear is not that we are inadequate. Our deepest fear is that we are powerful beyond measure. It is our light, not our darkness that most frightens us. We ask ourselves, who am I to be brilliant, gorgeous, talented, and fabulous? Actually, who are you not to be? You are a child of God. Your playing small does not serve the world. There is nothing enlightened about shrinking so that other people won't feel insecure around you. We are all meant to shine, as children do. We were born to make manifest the glory of God that is within us. It's not just in some of us; it's in everyone. And as we let our own light shine, we unconsciously give other people permission to do the same. As we are liberated from our own fear, our presence automatically liberates others." ***Marianne Williamson***

To my siblings **Tumelo** and **Omphile** thank you for always believing in me and for the support and encouragement that you gave me throughout my study.

This work is dedicated to my mother, **Manthepa Rosinah Sehoole**. Thank you for believing in my potential throughout my academic career, in my dreams and for being my rock and knowing that I have whatever it takes to move mountains. Thank you for all the love you have given me, and though there were times where I wanted to give up, you pushed me to go on and never gave up on me.

DECLARATION

I declare that the dissertation, which I hereby submit for the degree M Consumer Science: Food Management at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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Oratile Charmaigne Sehoole

January 2015

ETHICS STATEMENT

The author, whose name appears on the title page of this dissertation, has obtained, for the research described in this work, the applicable research ethics approval.

The author declares that he/she has observed the ethical standards required in terms of the University of Pretoria's *Code of ethics for researchers* and the *Policy guidelines for responsible research*.

ACKNOWLEDGEMENTS

I hereby wish to express my sincere gratitude and appreciation to the following people and institutions for the role they played in the successful completion of this study:

My study leader, Dr Annemarie Viljoen, and co study leader Dr Gerrie DuRand of the Department of Consumer Science, University of Pretoria, for their guidance and assistance in the writing up of the project;

My co-study Leader and colleague Dr Phillip Strydom, of the department of Meat Science, Agricultural Research Council for his assistance in the designing, execution and writing up of the project, and also for his encouragement, immense support and patience;

My colleagues Dr Ina van Heerden, Dr Michelle Hope Jones, Miss Tabea Mokhele and Ms Johanna Masilela for their assistance in the execution of the project and for their endless support and for encouragement;

MEATCO. Namibia for providing the samples and allowing me to use this project for my study;

The sensory panel of the Agricultural Research Council for their cooperation and time;

The biometry unit of the Agricultural Research Council for the statistical analysis of my data;

Mr Joseph Malemane, our family friend his help with the language editing of the dissertation and his valuable support and encouragement;

To all my close friends for showing interest in my study and always being there for me whenever the road looked long, dark and endless.

Last but not least to my Creator and Saviour with whom all things are possible…

SUMMARY

Sensory profiles and the effect of age, feeding regime and aging on quality of selected beef cuts

By

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The main purpose of this study was to determine, describe and compare the eating quality of selected beef cuts; loin, rump and ribeye produced in Namibia. These cuts originate from carcasses of different age classes, feeding regime and post-mortem aging periods. The determination of the eating quality of this beef will aid MEATCO in understanding consumers' responses in relation to the sensory attributes of these beef cuts. To date, the eating quality of this beef has not been determined or described by scientific means. Eating quality of beef refers to the overall beef eating experience and it can be affected by various pre- and post-mortem factors.

Eating quality is an important component of beef meat quality, but highly variable due to variations in tenderness and flavour, which are dependent on the intrinsic and extrinsic factors of the animal. This variability contributes to consumer dissatisfaction. As a result the prediction of eating quality of beef at the consumer level is of utmost importance to the producers of beef meat in order for them to remain competitive in the market.

The study was conducted in two phases, Phase 1 of the study involved descriptive sensory evaluation, where a trained panel was used to evaluate the beef samples. The sensory attributes that were applicable to the beef samples were first identified by the trained panel with the aid of the panel leader. From this, a lexicon and evaluation form were developed.

The trained panel used a category scale to rate the intensity of the identified sensory attributes. Phase 2 of the study involved physical evaluation, whereby measurements of shear force resistance were determined using the Warner Bratzler shear force device mounted on a Universal Instron Machine. Added to this cooking and thawing losses were also measured by using a measuring scale.

The results of the sensory evaluation show that the trained panel could distinguish the difference between the two grain fed groups (AG and ABG) and the young free-range group (AF) on one side and the older free-range groups (ABF, B4 and B6) on the other. The former groups scored higher for the attributes such as tenderness, overall flavour and aroma whereas the latter groups scored higher for juiciness and other flavour undertones e.g. green, livery, rancid and sour. Age class of the animals was found to have had an effect on tenderness related attributes and juiciness, whereas feeding regime had an effect on overall flavour and flavour undertones. However prolonged post-mortem aging had a minimal effect on the sensory attributes. There were no differences found between the 36 and 55 days aged samples.

From this study it can be suggested that even though extreme post-mortem aging results in acceptable tenderness levels for all age classes and feeding regimes, the consumer may still pick up flavour differences between the different age classes and feeding regimes. Marketing this beef as a single product line may therefore result in an inconsistent eating experience for the consumer.

Key Words: Eating quality, beef cuts, age class, grain fed, free-range, post-mortem aging, descriptive sensory evaluation and Warner Bratzler shear force

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CHAPTER 1

THE STUDY IN PERSPECTIVE

1.1 INTRODUCTION

Quality is described as the requirements necessary to satisfy the needs and expectations of the consumer and is one facet that is continuously being evaluated by consumers, whether they are aware of it or not (McWilliams, 2012: 41; Peri, 2006). The choice of a particular beef meat over another serves as proof that quality drives consumer acceptability of beef (McWilliams, 2012:41; Lawless and Heymann, 1998:17). The perception of consumers towards the quality of beef is critical for the beef industry because this perception has a direct impact on profitability (Troy & Kerry, 2010).

For the beef industry to be viable, there needs to be a demand for beef and ability for consumers to pay for it. For consumers to willingly purchase and consume beef, their perception must be positive towards it (Troy & Kerry, 2010). It is thus important that beef producers understand consumers' perception of beef quality in order for them to remain competitive in the market (Verbeke, Van Wezemael, de Barcellos, Kügler, Hocquette, Ueland & Grunert, 2010).

Beef quality can be defined from a functional or conformance point of view. Functional quality refers to desirable attributes in beef such as consumers expecting beef to be tender and flavoursome. Conformance quality refers to production of beef that meets consumers' specifications exactly, such as wanting beef steaks to be trimmed (Warriss, 2010:77). For this study, the definition of quality was from a functional point of view. Functional quality means different things to different people depending on where they stand in the production chain; whether they are a producer, processor, retailer or consumer (Warriss, 2010: 77).

Beef producers assess beef quality based on factors such as carcass composition and conformation to grade the quality of carcasses and cuts (Maltin, Balcerzak, Tilley & Delday, 2003). These definitions are narrow compared to those that the consumers use to define beef quality (Farouk, Al-Mazeedi, Sabow, Bekhit, Ayedemi, Sazili & Ghani, 2014). Consumers' definition of beef quality is often wide and subjective and often refers to eating quality with the focus on the sensory attributes, such as the appearance, colour, aroma, taste, tenderness and flavour (Farouk *et al.* 2014; Wismer, 2009; Hui, 2007). Ultimately the consumers' definition of beef quality is the most important as it drives the economy of the global beef industry (Moskowitz, 1995).

This study was concerned with the quality of beef, particularly of beef exported from MEATCO Namibia. In this study beef quality referred to eating quality. Eating quality refers to the overall beef-eating experience which is determined by the appearance tenderness, juiciness and flavour of the beef (Banovic, Grunert, Barreira and Fontes, 2009; Brunsø, Bredhal, Grunert & Scholderer, 2005).

1.2 PROBLEM STATEMENT

The eating quality of beef is an important and highly variable component of beef quality which contributes to consumer dissatisfaction (Hocquette, Van Wezemael, Chriki, Legrand, Verbeke, Farmer, Scollan, Polkinghorne, Rødbotten, Allen, Pethick, 2014). The variability in eating quality is brought about by variations in tenderness and flavour, which are dependent on the intrinsic and extrinsic factors of the animal (Destefanis, Brugiaplagia, Barge, & Dal Molin, 2007). The Namibian meat export company, MEATCO, exports predominantly free-range (grass-fed) and some grain-fed (feedlot) beef to the European Union and South Africa. Beef cuts exported to South Africa are mostly high quality cuts targeted for restaurant or barbeque purposes, such as the rump, sirloin and rib-eye. The cattle slaughtered by MEATCO for export are from different age classes, feeding regimes (free-range and grain fed) and breeds and the cuts are aged for various periods post-mortem depending on demand and turn over.

Currently, MEATCO exports A (0 tooth) and AB (1-2 tooth) class (South African Government Notice No. R.342 of 1999) grain fed and free-range beef to South Africa and this beef is marketed as one product line, but some of the variables mentioned (age class, feeding regime and post-mortem aging) play a critical role in the tenderness and flavour of beef which are the two most important eating quality attributes (Voges, Mason, Brooks, Delmore, Griffin, Hale, Henning, Johnson, Lorenzen, Maddock, Miller, Morgan, Baird, Gwartney and Savell, 2007; Killinger, Calkins, Umberger, Feuz & Eskridge, 2004). Complaints which are relative to the beef sold, have been received from South African consumers who are dissatisfied with the inconsistent eating quality of this beef.

MEATCO wants to add B (4-6 tooth) class beef (SA Government Notice No. R.342 of 1999) to the current product line, because of the belief that prolonged post-mortem aging will level out any differences brought by the differences in age classes, breeds or feeding regime. However, it is a concern that adding this age category to the current product line will result in a further variation in the beef which will have a negative influence on the eating experience of the consumer. It is therefore important to develop sensory profiles for the different cuts of beef as affected by the different variables (age, feeding regime and post-mortem aging) as this will aid in grouping similar beef cuts in the same product line. This grouping will reduce variability in the eating quality of the beef and the risk of consumer complaints.

1.3 JUSTIFICATION OF THE STUDY

The eating quality of Namibian beef has not been determined before. The determination of the eating quality of this beef will be beneficial to MEATCO as it will give them a complete depiction of the sensory profiles of the beef that the produce. They will, from these sensory profiles, see how the cuts differ from one another and how the different sensory attributes are perceived by their consumers. The results of this study will aid MEATCO in deciding whether or not to go ahead and market this beef (of different age classes, feeding regimes and aging) as a single product line for the South African consumer.

In conducting a literature review for this study it was evident that current scientific literature on the eating quality of beef especially from South Africa and Namibia is required. The information that was obtained was based mostly on literature from Australia, United States of America and European countries and this cannot always be applied in the South African context. There are also attributes like juiciness and aroma that have not received a sufficient amount of attention and specific scenarios of the effects of age classes, feeding regime and prolonged post-mortem aging are not extensively covered. This study will build on the literature that is currently available on the eating quality of Namibian beef.

1.4 RESEARCH AIM AND OBJECTIVES

1.4.1 Aim of the research

This research aims to determine and describe the eating quality of selected beef cuts, namely, loin, rump, and rib-eye produced in Namibia. These beef cuts originate from carcasses of different age classes, feeding regimes and post-mortem aging periods.

1.4.2 Research Objectives

The following objectives were formulated for the study according to the research aim:

Objective 1: To determine, describe and compare the sensory attributes of the three selected beef cuts (loin, rump and rib-eye) produced in Namibia.

Objective 2: To determine, describe and compare physical attributes of the three selected beef cuts (loin, rump and rib-eye) produced in Namibia.

Objective 3: To compile sensory profiles which will be used to compare selected beef cut product lines as affected by age, feeding regime and post-mortem aging period to understand consumers' responses in relation to the sensory attributes of these cuts.

1.5 STUDY AREA

The beef samples for this study were sourced from MEATCO in Namibia, but the study itself was conducted in South Africa at the sensory laboratory of the Agricultural Research Council in Irene. A trained panel was used to develop sensory profiles of the different beef cuts as they are affected by age classes, feeding regime and post-mortem aging.

1.5.1 Production of beef in Namibia

Namibia is regarded as an agriculturally unfriendly country due to the adverse climatic and soil conditions. Despite these unfavourable conditions, livestock production has established itself over the years and remains the lifeblood of the Namibian agricultural economy. This has enabled Namibia to become the biggest exporter of beef in Africa (Strydom & Müseler, 1997). The small population topped with low local beef consumption patterns results in the Namibian beef indstry being export orientated. Eighty five percent of Namibia's beef production is exported to the European Union (EU) and South Africa (SA) (Hengari, 2009). Exports have remained constant over the years with most of the beef being exported to South Africa. In

South Africa the cities or provinces that receive this export beef from Namibia are Cape Town, Gauteng and Durban (Strydom & Müseler, 1997).

Namibia is in good standing to export, because it has three EU approved beef export abbattoirs and two EU approved small stock abbattoirs as well as two South African approved beef export abbattoirs and two South African approved small stock abbattoirs available for international exports. Every year nine thousand tons of beef is exported from Namibia to the EU, Norway and Switzerland, whereas approximately twelve thousand tons is exported to South Africa (Hengari, 2009).

Namibia has an advantage in beef production because the country is sparsely populated, has large extent of pasture land, land is relatively affordable and labour costs are low. However, there are other negative factors that are impeding Namibia's advantage and causing the beef industry in Namibia to remain underdeveloped (Chiriboga, Kilmer, Fan, & Gawande, 2008). These factors include unattractive beef producer prices, animal health, trade agreements, herd structure and quality (Strydom & Museler,1997). Quality is one factor that is most relevant to the study and it will be briefly discussed.

Approximately 60% of Namibian beef production falls in the AB or B-age class (2-6 tooth) (Strydom & Müseler, 1997). The production of these age classes of beef satisfies the consumers in the EU as they require beef that is from carcasses originating from 18-42 months old animals (B2, B3 and B4). This, however, does not satisfy the South African consumer who is more acquainted to beef from a carcass originating from an animal that is less than 18 months old (A2, A3 and A4) (Zandeberg, 2013). In order for MEATCO to satisfy the South African consumer, they need to increase production of beef from the A-age class because they export the bulk of their beef to South Africa (Strydom & Müseler, 1997).

1.5.2 Beef consumption per capita in South Africa

Recent literature on beef consumption in South Africa is still lacking. South Africans are considered to be avid beef consumers but most are still eating less than the 80 g to 90 g of lean cooked beef a day recommended by the South African food-based dietary guidelines (Schönfeldt, 2013). The consumption of beef in South Africa has remained relatively constant at 14kg/capita over the past decade except for a slight increase to 16kg in 2005-06 (Index Mundi, 2014). Total beef consumption in South Africa has been on an increasing trend from

2003 to 2006 (see Figure 1.3) and decreased during 2007/08 (Department of Agriculture Forestry and Fisheries, 2011).

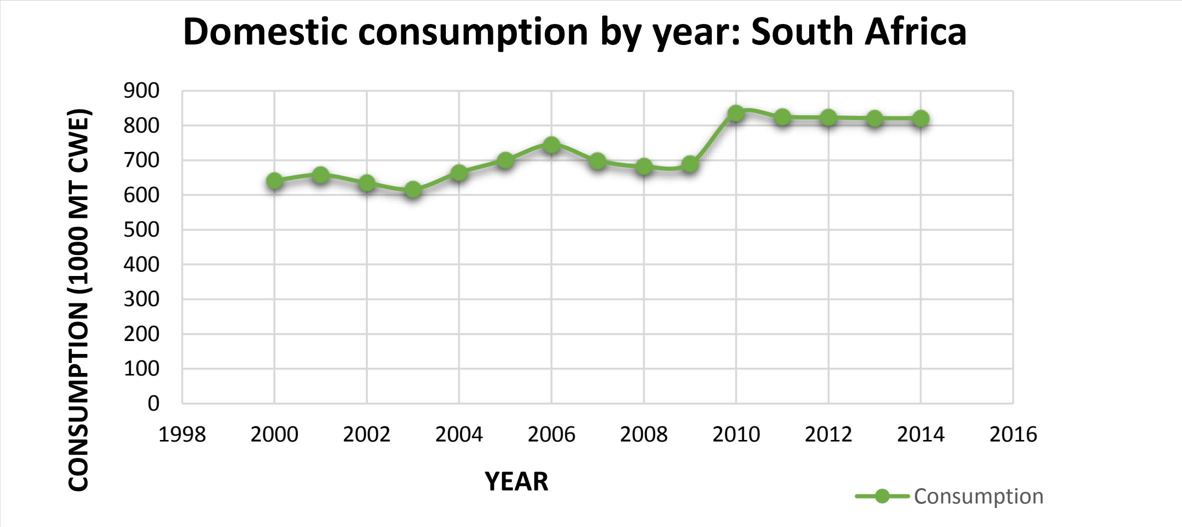


FIGURE 1.1: SOUTH AFRICAN BEEF DOMESTIC CONSUMPTION BY YEAR (Index Mundi, 2014)

The decline during 2007/08 to 2008/09 was due to the global economic recession, which led to a decrease in disposable income of a larger number of consumers (DAFF, 2011). During 2009/10 beef production and consumption experienced some increases because the global economic recession started to ease and South Africa was hosting the FIFA world cup. There was an increase of 54% in consumption during 2009/10 compared to 2000 (DAFF, 2011). From the year 2009 consumption of beef has been on an increase and this can be attributed to the increase in disposable income of consumers (DAFF, 2012a).

Consumption of beef in many countries has been affected by nutritional concerns about fat and cholesterol, which has encouraged production of leaner animals, closer trimming of outside fat on retail cuts of beef and substituting beef for poultry (Resurreccion, 2003). In South Africa fat content and other factors are taken into consideration by consumers when making beef purchases and will be discussed in the next section.

1.5.3 Considerations taken into account by South Africans when making beef purchases

A study of the trends in consumption of beef, has shown that the importance of factors such as income and price will decline over time whilst factors such as quality will become significant in influencing consumer choice (Taljaard, Jooste & Asfaha, 2006). Factors that affect demand for beef have been identified by Schroeder, March and Mintert (2000) as expenditure, food safety and health information. Consumers in all markets want beef that is tender, consistently high in quality, convenient to prepare, healthy and nutritious, safe and competitively priced (Verbeke, Perez-Cueto and Barcellos, Krystallis & Grunert, 2010).

Quality from the perspective of the consumer is subjective and can vary across individuals, societies and cultures (Henchion, McCarthy, Resconi & Troy, 2014). In South Africa the five most important considerations taken into account when purchasing beef are; price, expiry date, appearance, quality guarantee and fat content (Vermeulen & Bienabe, 2010). These considerations will be discussed individually.

- **Price**

Beef has traditionally been presented as a luxury product and increased consumption of beef has been linked to increased income (Spitters, Hoffman, de Schutter, & Leijh, 1998). The majority of consumers in South Africa are sensitive to price when it comes to beef purchases and price is probably the main factor limiting consumption of beef. (Schönfeldt, 2013; Labuschagne, Louw, & Ndanga, 2011). If the price of beef increases, then the demand decreases (Labuschagne *et al.* 2011).

- **Expiry date**

Fresh food products, beef included, have expiry dates presented on their packaging to guarantee quality towards consumers. Production companies are required by law to put a certain date on the package of food products even though no one governs them in determining the exact shelf life of that product (South African Government notice No. R 429 of 2014). Consumers buying beef from retail stores are usually faced with beef which has different expiry dates. It is assumed that whilst some consumers pick beef laying in front of the shelf some tend to pick beef laying at the back of the shelf in the hope of buying better and fresher beef with a longer expiry date (Tromp, Rijgersberg, Pereira da Silva, & Bartels, 2012).

- **Appearance**

The appearance of fresh beef is a determining factor in how consumers perceive quality of beef and it influences their purchasing behaviour (Ressureccion, 2003). The most important beef characteristic which consumers base their quality evaluations on are the appearance attributes: colour of beef, the density of the meat fibres, and the presence of fat (McIlveen &

Buchanan, 2001). Consumers use colour and the surface characteristics of the beef to establish quality of beef (Schor, Cossu, Picallo,Ferrer, Naon & Colombatto, 2008). The red/ pink colour is generally accepted by consumers worldwide as an indication of freshness of beef (Steenkamp & Van Trijp, 1996; Faustman, & Cassens, 1990). In South Africa it is recommended that beef should have a red to pink colour and have a medium to fine texture (DAFF, 2012b).

- **Quality guarantee**

Variable eating quality is a major concern for consumers worldwide and South African consumers should be no exception (Hocquette *et al*. 2014). Consumers want beef with consistently good eating quality. Evidence of this is seen by consumers willing to pay more money for guaranteed good quality beef (Monson, Sańudo & Sierra, 2005). If consumers are guaranteed consistent eating quality, their level of satisfaction increases, this leads to higher consumption rate and profitability for the chain stores (Verbeke *et al*. 2010). South Africans like "good quality beef' and to ensure that they get it, they purchase their beef from reliable butchers and retail outlets like Pick 'n Pay and Woolworths (Vermeulen & Bienabe, 2010).

- **Fat content**

Besides colour the next most important characteristic which consumers base their quality evaluation on, is fat content. (Morales, Aguiar, Suabiabre & Realini, 2013; Acebron & Dopico, 2000). Fat of any kind tends to be perceived negatively by consumers and the positive effects of fat that are linked to juiciness, flavour and tenderness are not always recognised by consumers. In general, consumers will not buy beef with obvious fat cover or marbling because it is viewed as less nutritious or not of good value (McIlveen & Buchanan, 2001). South African consumers generally want beef with lower fat content and fat class 2 carcasses/ cuts are usually ideal (Zandeberg, 2013).

These considerations tend to differ according to Living Standards Measure (LSM) groups. In South Africa the market is segmented through living standards measure (LSM groups), namely low LSM (Low income earners), Middle LSM (Middle income earners), High LSM (High income earners) (South African Audience Research Foundation, 2012). This LSM measures social class, or living standards regardless of race, income or education. LSM does not approach obvious demographic differences but rather focus on quantifying the ownership of durable goods and access to services to yield a composite measure of social class (Lamb, Hair, McDaniel, Boshoff, & Terblanche, 2008:47).

LSM 8 -10, which is the group most likely to consume beef produced by MEATCO, takes up 24.5% of the South African population (SAARF, 2012). LSM 8 focuses on price, expiry date and appearance in that particular order whilst LSM 9 and 10 focus on quality guarantee, price and then expiry date. Furthermore the selection of beef steaks is largely based on quality attributes and not on credence attributes (attributes that cannot be ascertained even after consumption of the product, e.g. hormone free beef, breed of the animal, friendly production practices) (Vermeulen & Bienabe, 2010).

1.6 RESEARCH DESIGN AND METHODOLOGY

This research was both exploratory and descriptive as the researcher wanted to gain insight into the problem and describe the panellists' perception of the sensory attributes (Babbie & Mouton, 2001:80). An experimental research design was employed for this exploratory and descriptive study and statistical methods were used to identify patterns and relationships in the data collected (Moody, 2002).

1.7 DATA ANALYSIS

Inferential statistical methods such as ANOVA (Analysis of Variance) and PCA (Principal Component Analysis) were used. Inferential statistics describes and summarises data in a way that has more meaning to the researcher as it aids in a better interpretation of data. Inferential statistics allow the researcher to make conclusions beyond the data analysed and to reach conclusions about any hypotheses that they might have (Laerd Statistics, 2003).

1.8 PRESENTATION AND STRUCTURE OF THE RESEARCH

CHAPTER 1: THE STUDY IN PERSPECTIVE

This chapter gave a definition of beef quality from a consumers' perspective. This was followed by a discussion of the study area, a summary of the objectives, research design and the analysis of data. The study will be discussed according to the following chapters and headings.

CHAPTER 2: LITERATURE REVIEW

In this chapter, concepts that are paramount to the study are introduced. The different variables that can affect eating quality are discussed, followed by their effect on the different sensory attributes of beef. The last part of this chapter gives a description of the methods employed to measure the eating quality of beef.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

The research design and methodology will be presented in this chapter. This will detail the plan on how the research was conducted and the tools and procedures used. The research was quantitative in nature and the data collection techniques used will be addressed. An experimental design was followed in this two-phase study. Phase 1 focused on sensory evaluation, where descriptive sensory evaluation was used to collect data. The standardised methods and procedures followed to collect this data are described. This is followed by Phase 2 of this study, which focused on objective evaluation, where physical attributes were measured by instruments. The standardised methods and procedure followed to collect this data is also described.

CHAPTER 4: RESULTS AND DISCUSSION

Sensory and objective results are presented and discussed in this chapter, and this is done according to the two phases in which the study was conducted.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

This chapter highlights the main findings and draws conclusions for the study. Limitations that were encountered in conducting this study are also specified and recommendations are made for future studies.

1.9 DEFINITIONS ACRONYMS AND ABBREVIATIONS

ABF	Beef carcasses from animals with 2 permanent incisors (free-range)
ABG	Beef carcasses from animals with 2 permanent incisors (grain fed)
AF	Beef carcasses from animals with 0 permanent incisors (free-range)
AG	Beef carcasses from animals with 0 permanent incisors (grain fed)
36	36 days aged beef
55	55 days aged beef
AMSA	American Meat Science Association
ANOVA	Analysis of Variance
ARC	Agricultural research Council
ASTM	American Standardised Testing Methods
B4	Beef carcasses from animals with 4 incisors (free-range)
B6	Beef carcasses from animals with 6 incisors (free-range)
DAFF	Department of Agriculture Forestry and Fisheries
EU	European Union
KZNDAE	Kwa Zulu Natal Department of Agriculture and Environmental Affairs
LSM	Living Standards Measure
MEATCO	Meat Corporation of Namibia
NDA	National Department of Agriculture
PCA	Principal Component Analysis
RSA	Republic of South Africa
SAARF	South African Audience Research Foundation
SAMIC	South African Meat Industry Company
USDA	United States Department of Agriculture
WBSF	Warner-Bratzler Shear Force

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The current study is concerned with determining the eating quality of selected beef cuts (loin, rump and ribeye) produced in Namibian in order to develop sensory profiles. This beef originates from cattle of various age classes raised under different feeding regimes and aged post-mortem for 36 and 55 days respectively. This review starts with a brief introduction of age classes of beef, followed by identification of beef cuts, beef cookery techniques and the factors that have an effect on eating quality. The last part of this review focuses on the measurements used to determine and describe the sensory and physical attributes relating to the eating quality of beef.

2.2 FACTORS AFFECTING THE EATING QUALITY ATTRIBUTES OF BEEF

The eating quality of beef is influenced by a variety of critical factors that begin with the pre harvest factors (age class of the animal, feeding regime, genetics and breed) and conclude with post-harvest factors (post-mortem aging and cooking) (Ferguson, Bruce, Thompson, Perry, & Shorthose, 2001). The major factors influencing eating quality are; age class, having a major impact on tenderness (Schönfeldt & Strydom, 2011b), feeding regime having the most impact on flavour (Maughan, Tansawat, Cornforth, Ward, & Martini, 2012; Melton, 1990; Shorthose & Harris, 1990) and post-mortem aging that has an impact on tenderness and to a lesser extent flavour (Jeremiah & Gibson, 2003; Spanier, Flores, Mcmillin, & Bidner, 1997). The factors that affect eating quality attributes in this study are discussed below:

2.2.1 Age class of the animal

Carcass classification or grading systems have been developed by various beef industries over the world to describe the quality and yield of a carcass (in particular the edible part) to the benefit of all role players in the production chain and for the final purpose of a satisfied consumer (Strydom, 2011). The terms grading and classification are often used interchangeably by consumers when discussing, carcass appearance, cuts, estimated yield and eating quality. Classification is defined as a set of descriptive terms describing the features of the carcass that are useful to those involved in trading of carcasses. Whereas grading, is defined as the placing of different values on carcasses for pricing purposes, depending on the market and requirements (Polkinghorne and Thompson, 2010).

Different countries over the world use different criteria in their beef classification and grading schemes, however age or maturity and marbling seem to be the main criteria used for these quality systems (Strydom, 2011). Although various countries or production systems rely on grading or classification systems to account for variation in quality, the criteria used often fails to account for all factors involved in this variation (Thompson, Polkinghorne, Watson, Gee & Murrison, 1999). The South African and Namibian classification systems are discussed further.

2.2.1.1 The South African and Namibian carcass classification systems

The single criterion used in the South African beef classification system in an attempt to distinguish between quality categories (mainly defined as tenderness) is based on the age of the animal which is scored by the number of permanent incisors (Government Notice No. R.342 of 1999). Since 1985 South African abattoirs have used the carcass grading system, where carcasses were graded in order of merit from the most preferred to the least preferred grades (KZN Department of Agriculture & Environmental affairs, 1992). This grading system was based on research conducted by Klingbiel (1984). Klingbiel's research found that beef from A- age animals of no more than two teeth had higher muscle collagen solubility and was more tender, juicier and lighter coloured than beef from older animals. After discussion by various committees a proposal was accepted to define age classes as A: 0 teeth, B: 1-6 teeth and C: 7 to 8 teeth (South African Government notice No. R1010 of 1981).

Numerous surveys conducted have shown that the consumer has little knowledge of the grading system and hence the need for a classification system arose (see Addendum F). (KZN Department of Agriculture & Environmental affairs, 1992). In the early 1990's research showed that tenderness, decreased with increasing slaughter age in the order; 0, 2, 4, 6 and 8 permanent incisors. Animals with 0 incisors were perceived to be more tender than those with 2 incisors and the 2, 4, and 6 teeth animals were not different in tenderness but the validity of these results was rejected. The authorities were then coerced to classify carcasses of 0 teeth as A- age, 2 teeth as AB age, 3-6 teeth as B- age (Strydom, 2011) see Figure 2.1.

In an attempt to ensure production of consistent quality of beef, the meat board of Namibia renders a classification service based on the South African classification system at all its export abattoirs. The carcasses exported to South Africa are checked and verified by SAMIC (South African Meat Industry Company). The carcass attributes recorded in the classification system are (KZN Department of Agriculture and Environmental affairs, 1992):

- Carcass mass which is recorded in kilograms (kg)
- Age of the animals by dentition (A, AB, B or C)
- Fat content of the carcass assessed visually (0-6)
- Carcass conformation assessed visually (1 to 5)
- Damage of the carcass (1 to 3)
- Sex which is only recorded in case of bulls in B and C grades

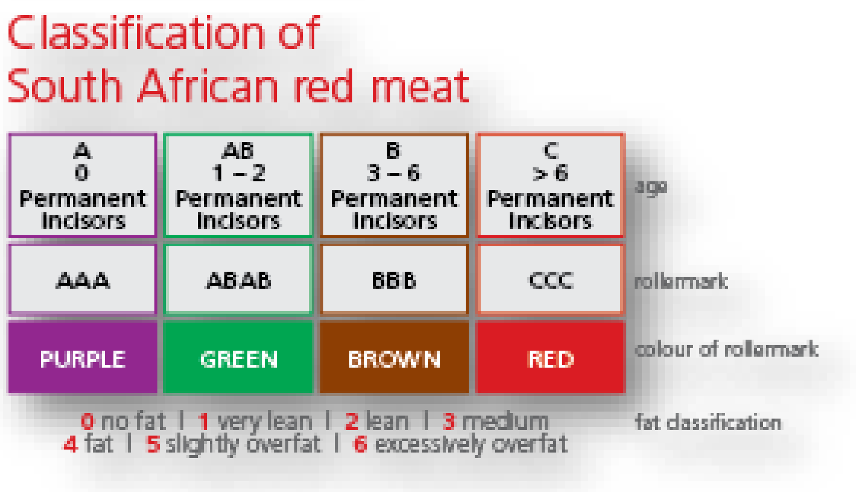


FIGURE 2.1: CLASSSIFICATION SYSTEM FOR RED MEAT IN SOUTH AFRICA (**Sparta, 2014**)

The sensory attributes of beef; juiciness, tenderness and flavour as they are affected by age are discussed in the sections that follow.

2.2.1.2 The effect of age class on juiciness

The age of an animal at slaughter has an influence on the perceived juiciness of beef (Du Plessis & Hoffman, 2007). When beef from different age classes (A, B, and C) was evaluated by a trained sensory panel it was observed that initial juiciness decreased as animal age increased (Schönfeldt & Strydom, 2011a). This decrease is brought about by inability of muscle to hold water with increased age. The result is higher cooking losses in beef from older animals and a drier end product which is not the case with beef from younger animals (Schönfeldt & Strydom, 2011a; Li, Xu, Zhou, Xu, & Zhang, 2007). Sustained juiciness on the other hand, tends to increase as animal age increases and this is because the beef from young animals has relatively little amount of fat, which gives a dry sensation compared to its older counterparts, which have more fat that has a stimulatory effect on salvation and gives a sustained impression of juiciness (Lawrie & Ledward, 2006: 303).

2.2.1.3 The effect of age class on tenderness

The chronological age of the animal is an important aspect in the context of beef tenderness as it has been consistently shown that beef from younger animals is more tender than beef from older animals (Schönfeldt & Strydom, 2011b;Shorthose & Harris, 1990). As the animal ages, beef palatability decreases due to decreasing amounts of heat labile collagen (Xiong, Mullins, Stika, Chen, Blanchard & Moody, 2007). Age of the animal, therefore, becomes a very important factor in determining tenderness and acceptability of beef (Schönfeldt & Strydom, 2011b).

Tenderness can be determined by the amount and solubility of the connective tissue (Koohmaraie & Geesink, 2006). The three connective tissues that bind and cover the muscle fibers are; perimysium, endomysium and epimysium (Harper, Allingham & Le Feuvre, 1999), these are illustrated in Figure 2.2. The connective tissue types consist of collagens that have the ability to form cross-links. As an animal matures, these cross-links become heat-stable, and the more heat-stable cross links present in a muscle, the tougher the meat will be (Avery, Sims, Warkupb, & Bailey, 1996).

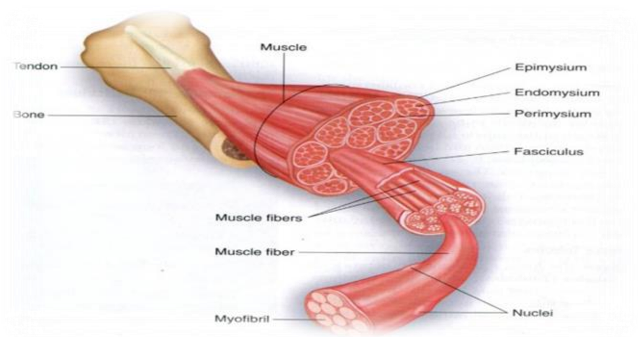


FIGURE 2.2: FUNCTIONAL ANATOMY OF THE SKELETAL MUSCLE AND MUSCLE FIBRES (Willmore, Costill and Kenney, 2008)

In the case of feedlot production, the more common form of production in South Africa, this is not really a factor when considering cuts like the rump (*M. gluteus medius),* fillet (*M. psoas*) and loin (*M. longissimus lumborum)* as these cuts have a low connective tissue content, because the animals are slaughtered at a young age before the cross-linkages of collagen can develop. However, in older animals often coming from pasture, this tenderness factor may become more prominent, in particular with cuts high in connective tissue like the cuts of the round and fore- quarter.

2.2.1.4 The effect of age class on beef flavour

The effect of animal age on flavour has not been widely explored thus very little scientific information has been documented on this relationship. Previous studies have indicated that palatability traits, flavour included tend to decrease with increasing animal maturity (Wood & Richardson, 2004; Miller, 2001). The desirability of flavour as a palatability trait tends to decrease with increasing animal age, but the effect of age of the animal on flavour profile is not always very clear, as it may interact with the feeding regime followed (Smith, Savell, Cross, & Carpenter, 1983).
Feeding regime as one of the variables affecting the attributes of eating quality of beef is discussed in the section that follows.

2.2.2 Feeding regime

The diet of cattle can either be grain-based (wheat barley, soya, maize, grain and other by-products) or forage based (grass, silage or hay). Animals fed on grain are usually termed grain fed or feedlot cattle, whereas those fed on forage can be termed free-range or pasture fed. The type of feeding regime that the animals are subjected to pre-slaughter can also affect the sensory attributes of beef, these are also discussed as they are affected by the feeding regime.

2.2.2.1 The effect of feeding regime on juiciness

Of late the effect of feeding regime on juiciness has not been thoroughly explored and still needs to be further investigated. Grain fed animals tend to have increased levels of marbling and minimal cooking losses compared to free-range animals (Hoving-Bolink, Hanekamp, &

Walstra, 1999). However the relationship between marbling and juiciness has not always been clear (Juárez, Aldai, López-Campos, Dugan, Uttaro & Aalhus, 2012).

2.2.2.2 The effect of feeding regime on tenderness

The nutritional status of cattle prior to slaughter can have an influence on muscle fibre type and collagen solubility, which ultimately determine beef tenderness (Thenard, Dumont, Grosse, Trommenchlager, Fiorelli, & Roux, 2006). The effect of feeding regime on tenderness has generated results that are conflicting. Some results indicate that animals fed on high energy diets (grain fed) tend to have an increased total collagen and an increase of collagen solubility (Schnell, Belk, Tatum, Miller, & Smith, 1997) whereas some found no effects (Thenard *et al.* 2006; Sami, Augustini, & Schwarz, 2004). Animals that are fed on pasture result in lower daily weight and lower protein turnover as a result of the constant movement which increases the collagen content and decreases the solubility of the collagen (Jurie, Picard, & Geay, 1998). The meat from these animals has a lower commercial value because it is usually tough and has higher Warner Bratzler shear force values compared to the meat from grain fed animals (Dufek, Bjelka, Šubrt, Simeonovová & Homola, 2008).

2.2.2.3 The effect of feeding regime on flavour

Feeding regime is known to affect the flavour of beef and this information is also obtained from much older studies with some conflicting results from newer studies. A wide range of results have been reported where some papers suggest that there are no differences in flavour of grain fed and free-range animals, whereas others state that there is a difference. In a study conducted by Melton (1990) it was concluded that feeds have an effect on the flavour of red meat. The more acceptable or intense beefy flavour in grain fed beef is attributed to the high energy diet of grain fed animals, as compared to the low energy diet of forage fed animals.

Free-range beef is often less desirable to consumers due to the presence of “off- flavours” such as sour and grassy (Brown *et al.* 1979 as cited in Melton, 1990). This beef also tends to develop fishy flavours during storage, which is not the case in grain fed beef. According to Wood, Richardson, Nute, Fisher, Campo, Kasapidou, Sheard and Enser (2003) beef flavour differences, under different feeding regimes is a result of variation in fatty acid composition. Fatty acids produce volatile, odorous and lipid oxidation products during cooking and the involvement of these, with Maillard reaction products; form other volatiles that contribute to odour and flavour. Unsaturated phospholipid fatty acids are particularly important in flavour development. In grain fed animals the C18:2:C18:3 fatty acid ratio is higher than in free-range animals and this ratio is associated with a "beef flavour" perception according to Wood, Enser, Fisher, Nute, Richardson and Sheard (1999). In contrast the higher proportions of C18:3 fatty acids in free-range animals are associated with the "grassy" flavour of free-range animals.

According to Jiang, Busboom, Nelson, Fallon, Ringkob, Rogers-Klette, Joos and Piper (2010) feeding regime had no effect on the flavour of beef and this was determined using both instrumental and sensory approaches. Studies that were carried out in the United States indicated that the consumers generally preferred grain fed beef over free-range beef. In South Africa, the feedlot (grain fed) industry produces approximately 70 to 80% of beef in the formal sector (NDA, 2003); from this it can be speculated that the South African consumer prefers grain fed beef.
In the next section attention will be given to post-mortem aging and its effect on the sensory attributes studied.

2.2.3 Post-mortem aging

Aging has been described as the improvement in palatability that occurs when beef is held post-mortem (Thompson, 2002). It is a natural process and especially beneficial to cuts from the rib and the loin. The two sensory attributes that are improved during aging are flavour and tenderness. After at least eleven days of post-mortem aging, the flavour of beef is developed and tenderness is improved (Epley, 1992). The effect of post-mortem aging on the different sensory attributes is discussed in the sections below.

2.2.3.1 The effect of post-mortem aging on juiciness

The effect of aging on juiciness is largely dependent on the relationship between aging and water holding capacity. Water holding capacity is defined as the ability of raw meat to retain moisture. This relates to the moisture inherent to the muscle tissue (Huff-Lonergan, 2009). There are three types of water that are found in the muscle namely; bound water (water that exists in the vicinity of non-aqueous constituents, such as protein and has reduced mobility), immobilised or entrapped water (water molecules in this fraction may be held either by steric effects and/or by attraction to the bound water that is held within the structure of the muscle but is not bound to protein) and free water (water whose flow from the tissue is unimpeded and mainly held by weak surface forces) (Huff-Lonergan, 2009).The reduction of water holding capacity can be achieved in one of the following ways, exudation of fluid known as "weep" in uncooked meat, or "drip" in thawed uncooked meat and as "shrink" in cooked meat. Post-mortem aging is believed to increase water retention and therefore increases water holding capacity of beef (FAO, 2012). From this, one can conclude that beef that has undergone proper aging would be perceived as more juicy than beef that has not been aged because the higher the water holding capacity the better the moisture in the beef will be retained on heating.

2.2.3.2 The effect of post-mortem-aging on tenderness

During the aging process beef is held at temperatures between 1 and 3°C (Teye & Okutu, 2009). This temperature coupled with extended periods allows proteolytic enzymes to break down complex proteins that are contained in the muscle (Lawrie & Ledward, 2006:315). Cathepsins which are naturally occurring enzymes in meat tenderise meat by slowly breaking down muscle fibres. They work on the bonds between the actin and myosin and contribute greatly to tenderness of meat (Feiner, 2006: 43).

Calpains (another type naturally occurring enzymes) also contribute to tenderisation of beef by cutting along the Z lines and long fibres into smaller units. Calpains activity is largely determined by temperature at which the beef is stored (Feiner, 2006: 43). If one freezes beef, calpain activity stops but the enzymes are not destroyed. This means that while the meat is frozen, enzyme activity remains paused, but on thawing, the activity is regained (Dransfield, 1992). Even with this knowledge that aging is a function of the calpain system the mode of action is still not fully understood (Hopkins & Thompson, 2002).

Post-mortem aging can also be affected by the type of beef cut, for example, high collagen muscles of certain fore quarter cuts (shin, chuck, brisket) and certain cuts of the hindquarter will be less affected by post-mortem aging compared to the loin or rump, which are low in collagen content (Rhee, Wheeler, Schackelford & Koohmaraie, 2004).

Post-mortem aging ensures that consumers are satisfied provided that age of the animal and connective tissue content are in favour of tenderness, i.e. the beef must be from a younger animal and connective tissue must be in low amounts and be heat soluble/labile. Aging can reduce shear force values after 10-14 days especially in the *M. longissimus lumborum* muscles (Wulf, Tatum, Green, Morgan, Golden & Smith, 1996; Geesink, Koolmees, Van Laack & Smulders, 1995; Mitchell, Giles, Rogers, Tan, Naidoo & Ferguson 1991). Although

Mitchell *et al* (1991) observed no further improvement after 21 days post-mortem aging, Moon, Hong, Kim, and Jung (1998) found that prolonged aging can improve tenderness of beef to up to 30 days.

2.2.3.3 The effect of post-mortem aging on flavour

It has been suggested by Elmore and Mottram (2009) that during the aging period there are microbial and enzymatic changes that occur in the muscle and these reactions are responsible for the alteration in the flavour profile of beef. Beef develops flavour as it is aged, and the flavour continues to improve to a certain point after which it begins to degrade and develops rancid flavours. Fatty flavour and positive flavour notes such as "beefy", "brothy" increase up to 14 days of aging where after, negative flavours such as "painty", "cardboard", "bitter" and sour start to develop and increase (Gorraiz, Beriain, Chasco, & Insausti, 2002). Aging for more than 21 days decreases the flavour identity and increases the development of metallic flavour, which is often detected after 35 days of storage (Yancey, Dikeman, Hachmeister, Chambers, & Miliken, 2005). The aging environment also has an effect on the final flavour. Aging beef by dry aging increases beef flavour intensities, brown and roasted aromas compared to beef aged in a vacuum or carbon dioxide packaging (Sitz, Calkins, Feuz, Umberger, & Eskridge, 2006; Campbell, Hunt, Levis, & Chambers, 2001). The factors affecting eating quality were discussed in this section (section 2.2).In the next section beef cuts that were focused on in this study, are discussed in detail.

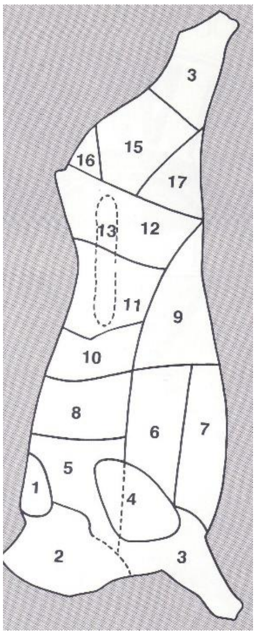
2.3 BEEF CUTS IDENTIFICATION

In South Africa and Namibia a live beef animal weighs approximately 440-460kg prior to slaughter (Sparta, 2014), and produces a carcass weighing between 260 and 265kg, which means approximately 55-59% of its live weight is represented (SAFA, 2014). At slaughter carcasses are split into right and left sides which weigh between 130-133kg each. Figure 2.3 shows a complete and split carcass of beef.

Carcasses are further divided into two forequarters and two hindquarters, usually between the tenth and the eleventh rib bone (Karan beef, 2014; Beefmaster, 2014). The forequarter is made up of cuts that have high levels of connective tissue and are best prepared by moist cooking to reduce the effects of connective tissue (Romans, Costello, Carlson, Greaser & Jones, 2001:562). The cuts of the forequarter are; hump, neck, shin, bolo, chuck, flat rib, brisket and prime rib (Samic, 2014).

FIGURE 2.3 COMPLETE AND SPLIT CARCASS OF BEEF

The hindquarter is the main source of high value steaks and these cuts tend to benefit from additional aging time (Romans *et.al.*,2001:562). The cuts of the hind quarter are; thin flank, wing rib, loin, rump, fillet, topside, silverside, aitchbone and thick flank (knuckle) (Samic, 2014). Figure 2.4 shows the different cuts of the fore and hind quarters of the carcass.



1. Hump
2. Neck
3. Shin
4. Bolo
5. Chuck
6. Flat rib
7. Brisket
8. Prime rib
9. Thin flank
10. Wing rib
11. Loin
12. Rump
13. Fillet
14. Topside (Behind 15 & 16)
15. Silverside
16. Aitchbone
17. Thick flank (Knuckle)

FIGURE 2.4 SOUTH AFRICAN BEEF CUTS

In this study the focus was on two cuts of the hindquarter; the loin and the rump and one cut from the forequarter, the rib-eye, presented in Figure 2.5.

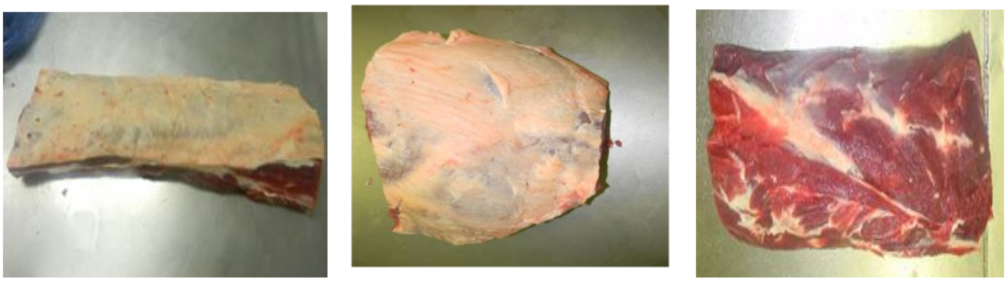


FIGURE 2.5: LOIN *(M. longissimus lumborum),* RIB-EYE *(M. longissimus thoracis),* and RUMP *(M. gluteus medius*)

According to Jeremiah, Dugan, Aalhus and Gibson (2003) different muscles of the beef carcass tend to differ considerably in terms in their sensory and physical attributes. Tenderness related differences among the different muscles of the carcass is mostly attributed to collagen concentration and properties, the state of contraction of the muscle (sarcomere length) and extent of proteolysis of myofibrillar and cytoskeletal proteins. The contribution of each of these factors to tenderness variation, differ among the various muscles of the carcass (Rhee *et al.* 2004).

Comparison of the eating quality attributes (initial tenderness, overall tenderness, juiciness, connective tissue and flavour desirability) of the loin, rib-eye and rump indicates that the rib-eye cut has the best eating quality of the three cuts, followed by the loin and then the rump (Hunt, Garmyn, O'Quinn, Corbin, Legako, Rathman, Brooks & Miller, 2014; Rhee *et al.* 2004; Jeremiah *et al.* 2003).

Measurement of the physical attributes of beef shows that the collagen content, Warner Bratzler shear force and cooking loss of the rump is higher than that of the loin (Hunt *et al.* 2014; Schonfeldt & Strydom, 2011b; Rhee *et al.* 2004). Currently, the rib-eye cut has been studied only in terms of its eating quality attributes and not on its physical attributes. But from the results of Jeremiah *et al.* 2003 it can be deduced that rib-eye has a lower collagen content and Warner Bratzler shear force than that of the loin and the rump.

2.4 EATING QUALITY OF BEEF

The eating quality of beef is determined by both physical and sensory attributes. Physical attributes refer to attributes such as instrumental tenderness, cooking and thawing losses (Vasanthi, Venkataramanujam & Dushyanthan, 2007). Sensory attributes refer to juiciness, tenderness and flavour of the beef (Maltin, Craigie, Richardson, Green, Picken, Roehe, Robertson, England, Glaseby & Ross, 2013; Hocquette, Renand, Levéziel, Picard & Cassar-Malek, 2006; Banovic *et al.* 2009; Brunsø *et al.* 2005). These attributes have the ability to influence consumers' acceptability and their decisions regarding beef purchases (Morales *et al.* 2013). It is important that beef is delivered to the consumer in a manner that promotes good, consistent eating quality and encourages consumers to make repeat purchases (Meat and Livestock Australia, 2014).

Juiciness is a critical attribute in determining overall eating quality of beef and it is positively related to the water holding capacity (Banovic *et al.* 2009; Brunsø *et al.* 2005; Joo, Kim, Hwang & Ryu, 2013). The degree of doneness of beef has an effect on the juiciness. In the initial stages of cooking some bound water in the meat gets converted to free water as the water binding capacity of meat is reduced. Between temperatures of 74^{o}C and 80^{o}C the rate at which bound water is converted to free water is rapid thus the water loss exceeds the conversion from bound to free water resulting in beef with reduced juiciness (Mcwilliams, 2012). Rare steaks (cooked to an end temperature of 60^{o}C) are juicier than steaks cooked to an end point temperature of 80^{o}C and 100^{o}C and as such for consumers to obtain desired levels of juiciness; they need to cook beef to an internal temperature of 70^{o}C and below (Winger and Hagyard, 1994).

Tenderness is also one of the most important factors in consumers' perception of beef quality (Verbeke *et al.* 2010; Miller *et al.* 2001), and consumers are willing to pay more for guaranteed tender beef (Monson *et al.* 2005). Consumers are also able to differentiate between a tender and a tough steak. A steak with a shear force value of 53N and above is considered tough, whereas a steak with a shear force value of 43N and below is considered to be tender (Destefanis *et al.* 2007). A steak with a shear force value of 40.2kg would result in a ninety eight percent acceptability level for consumers in both, home and restaurant settings (Rodas-González, Huerta-Leidenz, Jerez-Timaure & Miller, 2009; Huffman, Miller, Hoover, Wu, Brittin & Ramsey, 1996).

Flavour is also considered an important eating quality attribute, more so when tenderness is acceptable (Behrends, Goodson, Koohmaraie, Shackelford, Wheeler, Morgan, Reagan, Gwartney, Wise, & Savell, 2005; Killinger *et al.* 2004). According to Huffman *et al.* (1996) flavour was identified as the single most important factor in determining consumer acceptability when beef was prepared at home by consumers. A combination of juiciness, tenderness and flavour contributes to the overall eating experience of the consumer, because consumers prefer beef that is tender, juicy, has a fried flavour and no off flavours (Troy & Kerry, 2010; Banovic *et al.* 2009; Brunsø *et al.* 2005). The cooking method and the internal end point temperature, to which the beef is cooked, also have an effect on the eating quality of beef and these are discussed in the section that follows.

2.5 BEEF COOKERY

Cooking results in extensive changes in the appearance and physical attributes of beef. These changes are often dependent on cooking time, type of cooking method and temperature conditions (Rowe & Kerth, 2013; Resurreccion, 1994). According to McWilliams (2012: 344), there is a series of reactions that take place when beef is cooked. Firstly, the fat melts, proteins are denatured and water is lost from the meat. In the initial stages of cooking some bound water gets converted to free water as the water binding capacity of meat is reduced. This newly available water makes up for the water lost in the very early stages of meat cookery and as a result the meat remains juicy. Between temperatures of 74ºC and 80ºC the rate at which bound water is converted to free water is rapid, thus the water loss exceeds the conversion from bound to free water resulting in meat with reduced juiciness.

The degree of doneness of beef meat is subjective as it is often dependent on what the consumer prefers. Beef can be cooked to very rare (46-49ºC), rare (52- 54ºC), medium rare (54-60ºC), medium (60-66ºC), medium well done (68-74ºC) or well done (above 75ºC) (Labensky, Hause & Martel, 2014: 278). Beef can be cooked using different cooking methods, which can either be moist heat (uses high humidity or liquid to cook) or dry heat (uses dry high heat), and the best method to use is largely dependent on the cut (Rowe & Kerth, 2013). In conducting this study, dry heat cooking was used to prepare the beef samples that were evaluated.

2.5.1 Dry heat cooking

Dry heat cooking methods refer to those methods in which meat is surrounded by dry air in the oven or under a broiler (American Meat Science Association, 1978). This method is suitable for cooking of low connective tissue cuts of beef e.g. the loin because this type of cooking does not have the ability to solubilise collagen (McWilliams, 2012:374). Dry heat cooking methods, include, roasting, grilling, broiling and baking (Rowe & Kerth, 2013: 202).

2.5.1.1 Broiling

Broilling, the method used for this study, cooks meat by direct radiant heat. The meat can be placed below or above the heat source which radiates heat in one direction, so the meat needs to be turned during cooking (American Meat Science Association, 1978). This technique sears the outside of the meat and locks the juices within the muscle and is a method preferred to cook tender steaks (Rowe & Kerth, 2013; Resurreccion, 1994). This method is very common in research as it closely resembles the method used by consumers when cooking beef (AMSA, 1978). This type of cooking generally cooks the meat quickly and can impart flavour through Maillard reaction. This reaction occurs when a reducing sugar and a protein in meat react in the presence of high heat (usually above 148^{0}C) (Rowe & Kerth, 2013; Feiner, 2006:70).

2.6 SENSORY EVALUATION OF BEEF

Beef can be evaluated using both sensory and objective methods. In this section sensory evaluation will be discussed, followed by objective evaluation in the next section.

Sensory evaluation is defined by Stone and Sidel (1993:12) as a scientific discipline used to evoke, measure, analyse and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, touch and hearing. Foods have several characteristics that are evaluated by sensory methods in order to gain an understanding of the human perception of these foods (McWilliams, 2012:46). Consumers use sensory properties as indicators of quality throughout all the stages of the beef selection, purchase, storage, preparation and consumption (McIlveen & Buchanan, 2001).

The three most important properties that consumers use to judge beef are appearance, texture and flavour (Schor *et al*, 2008). Of these three, appearance is most important at the point of purchase as it influences purchasing decisions (Issanchou, 1996). This is followed by sensory evaluation with respect to flavour. After cooking, if the flavour is acceptable the consumer desires beef to be tender (O'Sullivan & Kerry, 2009). Quality attributes are perceived in a certain order during the sensory experience of beef, namely appearance, odour/ aroma, juiciness, tenderness and flavour (Meilgaard, Civille & Carr, 2007).

Sensory evaluation is commonly used in studies relating to beef and can be performed by either a trained or an untrained (consumer) panel (O'Sullivan & Kerry, 2009). A trained panel is a sensory evaluation panel that has been given thorough training regarding the use of the scorecard and the evaluation of the various characteristics included in the evaluation (McWilliams, 2012:52). An untrained or consumer panel is an evaluation panel that has not been trained specifically regarding the product evaluation being undertaken in the study. These can be people who happen to be available and are willing to participate (McWilliams, 2012:52).

There are three types of sensory tests that can be applied when evaluating meat, namely; Discrimination testing, descriptive analysis and affective testing. As a result, there are three types of panels that can be used in evaluating meat products, namely: "difference" testing panel and "descriptive attribute" testing panel and consumer panel (O'Sullivan & Kerry, 2009). Discrimination tests tell the researcher whether there is a detectable difference between samples. The common difference test methods are: triangle test, duo trio test "A" – "not A" test (Lawless & Heymann, 1998). Although these methods are powerful tools, they are not practical in meat studies as they require that only one sensory attribute varies independently of the other sensory attributes (Byrne & Bredie, 2002).

Descriptive analysis was used for this study due to the complexity of the sensory attributes involved. Descriptive analysis is defined as a sensory methodology that provides quantitative descriptions of products based on perceptions of a group of qualified subjects (O'Sullivan & Kerry, 2009). It is a total sensory description, taking into account all the sensations perceived namely; visual, auditory, olfactory, and kinesthetic – when a product is evaluated (Stone & Sidel, 1993: 203). Descriptive panellists themselves, firstly determine the descriptive vocabulary (lexicon) for beef; these describe specific sensory attributes in a beef sample and are used to evaluate relative changes in these attributes. Affective testing usually follows discrimination and descriptive tests. This type of test measures the degree of liking or preference of meat by potential or current consumers (O'Sullivan & Kerry, 2009).

Descriptive analysis methods have been developed over the last 40 years and some of these methods have gained and maintained popularity (Meilgaard *et al.* 2007: 178).There different test methods that can be used when applying descriptive sensory analysis; flavour profile®, texture profile, quantitative descriptive analysis (QDA®), the spectrum descriptive analysis, time-intensity descriptive analysis and the free-choice profiling. Only quantitative descriptive analysis will be discussed because the generic, non-commercial format of QDA® was used for this study. The descriptive sensory method used in this study is based on the American Meat Association (AMSA) guidelines for sensory evaluation of meat.

2.6.1 Quantitative Descriptive Analysis®

QDA® is a method that was developed in the 1970's by the Tragon Corp. to correct some of the perceived problems associated with the Flavour Profile. QDA® is characterised by unstructured line scales which are used to describe the intensity of rated attributes (Lawless & Heymann, 1998: 351). This method is highly reliant on statistical analysis to determine appropriate terms, procedures and panellists that are to be used for analysis of products (Meilgaard *et al.* 2007:180).

Panel members are screened for their ability to discriminate between different food samples. This starts with an introductory course during which the panellists will be exposed to four basic tastes (i.e. sweet, sour, salty, bitter and umami) and thresholds tests for these tastes are also performed (Jellinek, 1985:15). Triangle tests are also usually effective for screening tests (AMSA, 1978). After the panel has been recruited and screened, further training is applied on a specific product that is being evaluated, in this case beef. The objectives of the training phase as stated in (AMSA, 1978) are to:

- Familiarise an individual with test procedures
- Improve individual ability to recognise and identify sensory attributes
- Improve an individual's sensitivity and memory, permitting precise and consistent sensory judgements.

The training phase of descriptive sensory analysis begins with the development of a common scientific language, which gives a comprehensive description of attributes, this is usually termed "lexicon". References and standards are agreed upon. This lexicon is then used by the panel throughout the evaluation process (Murray, Delahunty, & Baxter, 2001). Following training, panellists evaluate the products in separate booths and the results obtained are then analysed statistically (Meilgaard *et al.* 2007: 180).

2.6.2 Sensory attributes of beef

Sensory attributes of beef are the main determinants of beef's eating quality. The measurement of sensory attributes and the determination of their importance to beef acceptance is said to represent major accomplishments in sensory evaluation. The acceptability of beef is based on qualities that human beings define and perceive with their senses. These qualities are described as sensations and are referred to as sensory attributes. For purposes of this study, these include perceptions of aroma, juiciness, tenderness and flavour (Molnar, 2009). These sensory attributes are discussed as follows:

2.6.2.1 Aroma intensity

Aroma intensity refers to the overall beef odour that is detected by the olfactory system and is pleasant (Braghieri, Piazzolla, Carlucci, Monteleone, Girolami, & Napolitano, 2012; Feiner, 2006:566)**.** Aroma is evaluated by sniffing the meat and it is advisable to fan the air around the sample so as to direct aromatic compounds towards the nose with the hand. Beef is best evaluated whilst it is still warm as the volatility of the aroma is related to the temperature of the meat. High temperatures tend to volatilise aromatic compounds making them apparent for judging (McWilliams, 2012:48).

2.6.2.2 Juiciness

Juiciness is defined as the amount of water retained in the meat after the meat has been cooked (FAO, 2012). Juiciness has two sensory properties; the first one is the impression of moisture or release of moisture during the first few chews resulting from the rapid release of beef fluid whereas the second one is the sustained presence of moisture as a result of the stimulatory effect of fat on the saliva (Weir, 1960 as cited in Lawrie and Ledward, 2006: 302). Juiciness plays a significant role in the texture evaluation of beef, and unlike other aspects of texture, juiciness is strictly a subjective attribute as it cannot be measured by objective methods (Winger & Hagyard, 1994). The extremes of juiciness are dryness and succulence (Warriss, 2010)**.**

2.6.2.3 Tenderness

Tenderness refers to the minimum force required to chew the meat sample, the lower the force the higher the tenderness (Braghieri *et al.* 2012). In cooked meat, tenderness is measured by resistance to tooth pressure and ease of fragmentation. These are referred to as initial and sustained tenderness measured by initial bite (force to bite through) and chewiness (how long it takes for the meat to disintegrate into pieces) (Kerth, 2013: 99).

One of the oldest methods developed to assess the texture of meat include the chew count (panellists count the number of chews to reduce the product to the necessary size needed for swallowing) (Harrington & Pearson, 1962). Panel members may differ in their chew count but this method was developed so that tenderness can be described on a quantitative basis (O'Sullivan and Kerry, 2009).

2.6.2.4 Typical Beef flavour

Flavour refers to the combination of taste, aroma and tactile stimuli perceived while chewing and swallowing- referring to the typical beef flavour (Braghieri *et al.* 2012. Flavour is often evaluated subjectively by the level of acceptability of the overall flavour. It is of importance that the temperature is appropriate for serving so that the evaluator will be able to detect the flavour of the beef (McWilliams, 2012:49). Sensory evaluation has been used in studies to identify both desirable and undesirable meat flavours (Maughan *et al.* 2012).

2.7 PHYSICAL EVALUATION OF BEEF

Sensory evaluation gives important results, but because of its reliance on human subjects, the results are often variable (Meilgaard *et al.* 2007: 2). As a result objective methods that do not rely on human senses are often used in research. There are many advantages to objective evaluation such as; they offer a permanent record of results, they invite confidence because they are reproducible and less subject to error than sensory evaluation methods (Campbell, Penfield, & Griswold, 1980:451). It is important that one selects objective tests with care because the results of objective evaluation must be in agreement with those of sensory evaluation. If the two methods do not correlate they may not be measuring the same component of quality and the physical method may be of no use to the study (Campbell *et al.* 1980:452). The two objective tests that were used for this study are; shear force measurement and cooking losses and they will be briefly discussed.

2.7.1 Shear force resistance (Warner Bratzler method)

The Warner-Bratzler method has been used by several researchers (O'Sullivan & Kerry, 2009; Miller, Carr, Ramsey, Crockett, & Hoover, 2001; Shackleford, Wheeler, & Koohmaraie, 1997) and was used for this study to measure tenderness in addition to sensory evaluation. The Warner Bratzler shear method measures the tenderness of meat, by measuring the force required to shear a sample of cooked meat (Kerth, 2013 107; McWilliams, 2012:76). This method was developed in 1930 and it is the most widely used in physical measurement of beef tenderness.

Shear force measurements are a good measure of protein tenderness but they are not good with describing differences in textural properties when there is a difference in connective tissue. Hence shear force is usually used in cuts with low connective tissue, such as the cuts used in this study, loin, rib-eye and rump. (Kerth, 2013: 107). Although very popular, it is very time consuming because a steak has to be cut from the carcass, aged and then destroyed, unlike in other methods such as Meullet-Owens razor shear and infrared spectroscopy. However, of all these methods Warner Bratzler shear force is the one method which is closely related to tenderness as measured by a trained panel (Yancey, Apple, Meullenet, & Sawyer, 2010; Montgomery, 2007).

2.7.2 Cooking losses

Cooking losses are a result of fat that has melted to form drippings, evaporation of moisture and other volatiles (Resurreccion, 1994: 40). Cooking loss is often associated with degree of doneness in steak. Dry heat cooking such as grilling tends to increase the amount of cooking loss, as a result of high cooking temperatures that are capable of evaporating liquids leading to increased moisture loss (Rowe & Kerth, 2013).

2.7.3 Thawing losses

Thaw loss is a reduction in water holding capacity which is achieved by exudation of a fluid known as ‘drip’ in thawed uncooked meat (Huff-Lonergan, 2009). The amount/ rate of thaw loss may be affected by the aging degree of beef prior to freezing, freezing type (slow vs. fast) and storing conditions while freezing. (Gambuteanu, Borda & Alexe, 2013). The temperature at which beef is stored at during thawing, type of packing (vacuum packaging will result in higher drip loss as vacuum will impart some physical force on the meat) and the dimensions of the beef (a thinner slice of beef will have proportionally more drip loss as compared to a thicker sliced beef) are some of the factors that may also affect thawing loss. Steaks and chops in their packaging are thawed at 2- 5 ^{o}C for 18-24 hours (AMSA, 1978).

2.8 SENSORY PROFILES

Descriptive sensory data is mainly used for sensory profiling. Sensory profiling refers to the description of the sensory properties of a sample, comprising the sensory attributes in the order of perception, and with the assignment of an intensity value for each attribute (British standards, 2003). The description of each beef cut in terms of detailed attributes and attribute intensity provides a thumbprint of the cut in words or in numbers that characterise aroma, juiciness, tenderness and flavour of the beef cut.

Sensory profiling is a powerful tool for the entire food industry as it can provide important information for the development and marketing of new products, the reformulations of existing ones and optimisation of the manufacturing process (Meilgaard *et al.* 2007; Stone & Sidel, 1993). In this study the sensory profiles were developed based on the results of the trained panel. These profiles can be used by the meat producer (MEATCO) to verify the effects of various pre-slaughter and post-slaughter factors on the final eating quality of their different product lines. These profiles can further be used to decide whether or not marketing beef of different age classes, feeding regimes and post-mortem aging as a single product line is viable.

2.9 CONCLUDING SUMMARY

In this chapter eating quality as the main concept of this study was discussed in terms of its sensory and physical attributes. The different variables that were studied (age class, feeding regime and post-mortem aging) were also discussed in how they relate/ affect the different sensory attributes. In the last part of the chapter, the two measurement techniques, namely descriptive sensory evaluation and objective evaluation also received attention. The next chapter discusses the methodology that was followed in the study.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

This chapter will deliver an outline of the research methodology followed in each phase of the study and includes the research design, research objectives, conceptualisation, operationalisation, data analysis as well ethical issues that needed to be considered before execution of the study. The research design which serves as a blueprint for how the study was completed will be discussed first (Babbie & Mouton, 2001:74).

3.2 RESEARCH DESIGN

This study was quantitative in nature as the emphasis was on the quantification of the constructs and examination of relationships among variables (Creswell, 2014:4; Babbie & Mouton, 2001:49). The approach of a quantitative study is that from the positivistic paradigm, because of the nature of controlled settings and the belief that the only way to measure properties of the phenomena under study is through quantitative measurements, i.e. assigning numbers to the perceived qualities of things (Kumar, 2014:133; Babbie & Mouton, 2001:49).

The approach of this research was exploratory and descriptive (Babbie & Mouton, 2001:81). It was exploratory because the eating quality of selected Namibian beef cuts has not been determined before Then again the study was also descriptive because the researcher wanted all the measuring tools (the panellists and Warner bratzler shear force device) to give a description of the eating quality of the beef cuts studied.

An experimental research design which is mostly associated with structured science was implemented for this exploratory and descriptive study. The most conventional type of experiment to be used in any area of study involves one of the three major pairs of components: (1) dependent and independent variables, (2) pre-testing and post testing, (3) experimental and control groups (Babbie & Mouton, 2001: 209).

This study had three independent variables: the age classes of the carcasses (A, AB B) (Government notice No. R.342 of 1999), feeding regimes of the animals (grain and pasture) and the post-mortem aging period of the carcasses (36 and 55 days). The dependent variables were all the sensory and physical attributes that were measured, in this case the aroma intensity, juiciness, tenderness, typical beef flavour, flavour undertones, shear force, cooking and thawing loss. The control samples are the A group cuts and the experimental samples are the AB, B4 and B6.

In phase 1 of the study, sensory data was gathered by means of a sensory evaluation form, where each panel member had to evaluate a set of thirteen attributes for each sample of meat given. In phase 2 of the study objective data was gathered by means of a cooking data form to calculate thawing and cooking losses. The Warner Bratzler shear device mounted on a Universal Instron Machine (Instron 4500, series IX version 5, Massachusetts) was used gather shear force data.

3.3 RESEARCH AIM AND OBJECTIVES

The overall research aim of this study is to determine and describe the eating quality of selected beef cuts (loin, rump, rib-eye) produced in Namibia and originating from different age classes, feeding regimes and post-mortem aging periods. This will aid in understanding how the different variables mentioned affect the overall eating quality of meat. The following objectives directed the research design and methodology:

- To determine, describe and compare the sensory attributes of the three selected beef cuts (loin, rump and rib-eye) produced in Namibia.

  The sensory attributes of aroma, juiciness, tenderness and flavour were relevant to the study and were determined and described.

- To determine, describe and compare physical attributes of the three selected beef cuts (loin, rump and rib-eye) produced in Namibia.

  The physical attributes of thawing, cooking losses and shear force resistance were determined as they were applicable to the study.

- To compile sensory profiles for the selected Namibian produced beef cuts as affected by age, feeding and post-mortem aging. These will be used to compare and understand consumers' responses in relation to the sensory attributes of these beef cuts.

3.4 EXPERIMENTAL DESIGN AND CONCEPTUAL FRAMEWORK

The conceptual framework which also serves as the experimental framework for this study on the eating quality of the selected beef cuts produced in Namibia is presented in Figure 3.1. The framework indicates at the top the samples (the selected three beef cuts; loin, rib-eye and rump) to be analysed in this study. These are followed by the independent variables (factors that may have an influence on the eating quality; age classes, feeding regime and post-mortem aging).Then the method used to cook the samples (dry heat cooking), the two data collection phases of the study; Phase 1 and Phase 2.

Phase 1 focused on the descriptive sensory evaluation where the sensory attributes of aroma, juiciness, tenderness and flavour were evaluated by a trained panel. Phase 2 was concerned with physical evaluation where the Warner Bratzler shear force device and measuring scales were employed to measure meat tenderness, thawing and cooking losses. The data obtained from these two phases was used to determine eating quality and thereafter sensory profiles were developed.

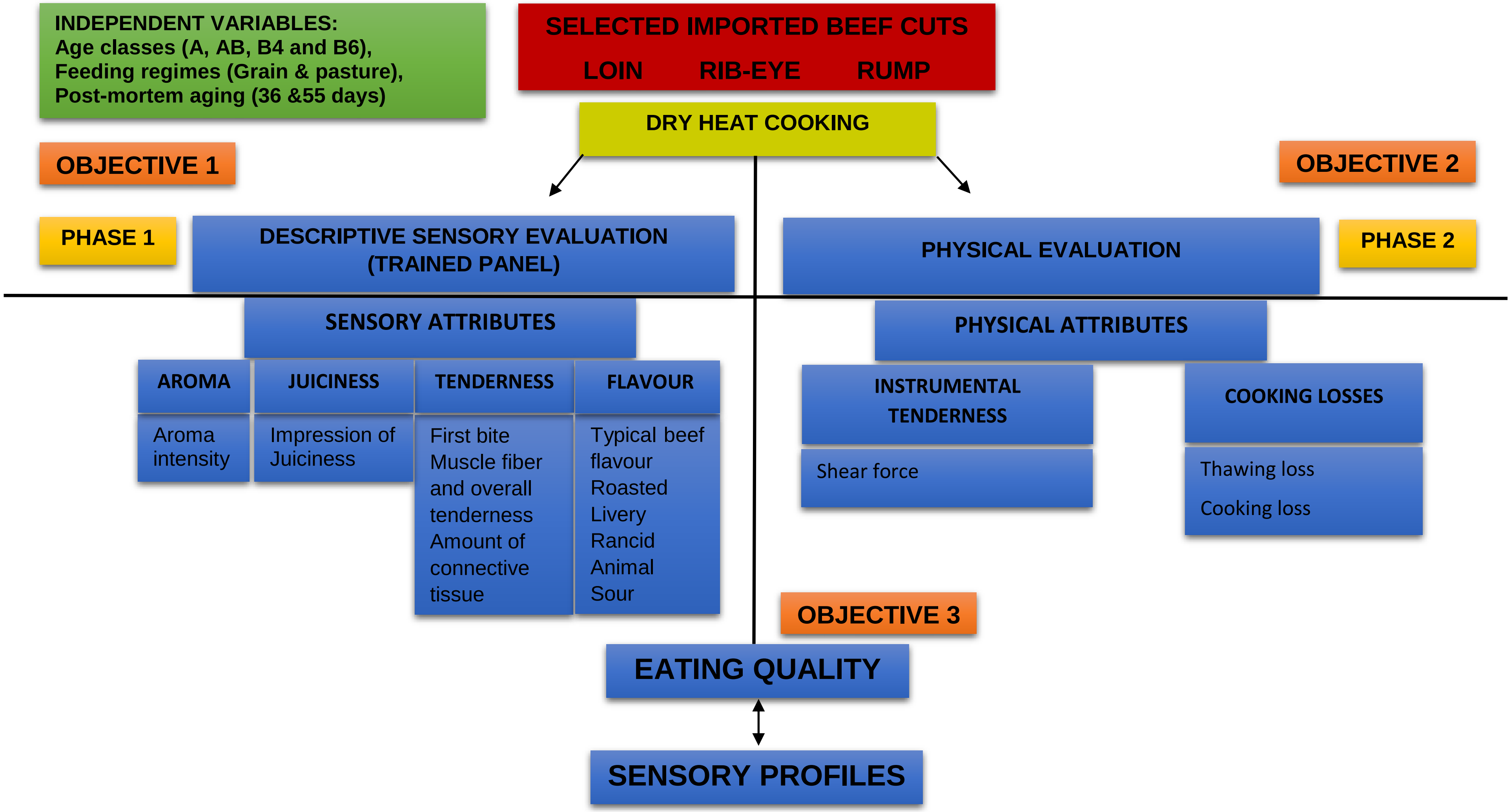


FIGURE 3.1: EXPERIMENTAL DESIGN AND CONCEPTUAL FRAMEWORK

3.5 CONCEPTUALISATION

Conceptualisation is the process through which concepts used in the study are made more specific and precise (Babbie & Mouton, 2001:640). Certain concepts that are fundamental to this study, these are conceptualised as follows:

Loin *(M. Longissimus lumborum)*. This is a cut from the striploin and mainly consists of a muscle that does very little work and it is particularly tender (Ohio Sand Farm, 2013). It is usually prepared by broiling and pan frying (Meals for you, 2014).

Rump *(M. Gluteus medius*) is a tender cut that consists of three loosely connected muscles and the pelvic bone which consists of the hip and aitchbone (Karan Beef, 2014). However the *gluteus medius* is the largest part and the one that was used in this study. It is usually prepared by broiling and pan frying (Meals for you, 2014).

Rib-eye (*M. Longissimus thoracis*) is cut across the grain from the rib-eye roast, it has little or no fat cover and is usually prepared by, broiling or panfrying (Meals for you, 2014).

Age classes refer to the different groups under which the cattle are classed based on their maturity. Age and marbling are the most common criteria used for quality grading and classification. In South Africa, the maturity of the animal is determined by dentition (Strydom , 2011).

Free-range cattle are cattle whose diet is forage based (grass, silage or hay) (Elmore & Mottram, 2009).

Grain fed cattle are cattle whose diet is grain based (wheat, barely, soya, corn) (Elmore & Mottram, 2009). These cattle are fed on grain to achieve the best quality objectives that satisfy consumer preferences. This is a common practice in South Africa (SAFA, 2013).

Post-mortem aging refers to the extended time of storage beyond the resolution of rigor. Carcasses or meat is held in refrigerated temperatures for extended periods of time (between 2-4 weeks), after slaughter and initial chill; this helps improve tenderness and flavour of meat.(Braden, 2013; Lawrie and Ledward, 2006:315).

Dry heat cooking method refers to any cooking technique where the heat is transferred to the meat without using any moisture. Dry-heat cooking typically involves high heat, with temperatures of 150ºC or warmer (McWilliams, 2012:374)**.**

Quantitative Descriptive Analysis® is a descriptive analysis method that is based on the principle of a panellist's ability to verbalize perceptions of a product (Meilgaard *et al.* 2007:180; Stone & Sidel, 1993:216). The method represents a formal screening and training of panellists, development and use of sensory terminology and scoring of products to obtain a complete quantitative description (Hayes, 2011).

Trained panel is a sensory panel that has been thorougly trained regarding the use of the scorecard and evaluation of different characteristics (McWilliams, 2012:52).

The **sensory attributes aroma, juiciness, tenderness** and **flavour** are evaluated. **Aroma** is the odour of meat and this quality can be detected when the volatiles of meat enter the nasal passage and are perceived by the olfactory system (Meilgaard *et al.* 2007:8; Jellinek, 1985:111). In the study only aroma intensity was measured. **Juiciness and tenderness** are qualities which are evaluated in the mouth (McWilliams, 2012:49). Within the sensory attribute juiciness, the impression formed as one starts chewing was evaluated (Lawrie & Ledward, 2006:302). Within the sensory attribute overall tenderness, dimensions of initial ease of penetration of the meat by the teeth, the ease with which the meat breaks into fragments and amount of residue remaining after chewing were evaluated (Weir, 1960 as cited in Lawrie & Ledward, 2006:304). **Flavour** is a sensory message resulting from a combination of taste and aroma (McWilliams, 2012:49). Within the sensory attribute flavour, dimensions of typical beef flavour, roasted, livery, rancid, animal, sour and green were evaluated.

Physical evaluation involves measurement of physical properties of meat samples by the use of mechanical devices. The goal is to obtain highly reliable data that can be compared to results obtained by sensory evaluation (McWilliams, 2012:71). In this study the physical evaluation included shear force resistance measurements which measured tenderness and a measuring scale which was used to measure thawing and cooking losses.

Shear force resistance measurement refers to the measurement of the force required to shear a sample of cooked meat with tensile strength (McWilliams, 2012:76).

Cooking losses refers to the amount of moisture that is lost by the steaks during the cooking process (Rowe & Kerth, 2013).

Thawing loss refers to the reduction in water holding capacity which is achieved by exudation of a fluid known as 'drip' in thawed uncooked meat (Huff-Lonergan, 2009).

Eating quality refers to a combination of several impressions obtained when meat is eaten; it is what the consumer perceives when eating cooked meat. The eating quality of meat relates to the attributes of aroma, juiciness, tenderness and flavour (Meinert, *et al.* 2008; Smith, Tatum & Belk, 2008).

Sensory profile is a measure of the overall impact (intensity) of all the aroma, juiciness, and tenderness and flavour components of meat as perceived by the panellists (Meilgaard *et al.* 2007:176).

3.6 OPERATIONALISATION

Operationalisation refers to the way in which the concepts in the conceptual framework are measured, this is shown in table 3.1 (Babbie & Mouton, 2001:128). Due to the nature of this study the eating quality of the selected beef cuts produced from Namibia was determined utilising only quantitative methods (sensory evaluation techniques and objective evaluation measures).

TABLE 3.1: OPERATIONALISATION TABLE

OBJECTIVES	MAIN CONCEPTS	DIMENSIONS	INDICATORS	MEASURING INSTRUMENT
To determine, describe and compare the sensory attributes of each of the three selected import beef cuts (loin, rump and rib-eye)	Sensory quality	Aroma Juiciness Tenderness Flavour	8- point category scale	Trained descriptive evaluation panel
To determine, describe and compare physical attributes of each of the three selected import beef cuts (loin, rump and rib-eye)	Physical quality	Instrumental tenderness Thawing loss Cooking loss	Peak force (Kg) Calculation (g) Calculation (g)	Warner Bratzler shear force attachment Measuring scale Measuring scale
To compile sensory profiles which will be used to compare selected import beef cut product lines as affected by age, feeding regime and post-mortem aging period to understand consumers' responses in relation to the sensory attributes of these cuts.	Sensory profiles	Aroma Juiciness Tenderness Flavour	PCA's Spider plots	Descriptive sensory analysis

3.7 MEASURING TECHNIQUES

Two types of measuring techniques were used in this study; sensory evaluation and objective evaluation. These techniques are discussed in detail in the following sections. Quantitative descriptive analysis was applied in the first phase of the study as such it will be discussed first.

3.7.1 Sensory descriptive analysis

The descriptive analysis of beef requires a descriptive technique and a lexicon to describe the sensory attributes. The results obtained from descriptive analysis tests provided a complete sensory description of each of the selected beef cuts, the basis for mapping differences and similarities between these cuts and also a basis for determining those sensory attributes that are most important for consumer acceptance.

Eating quality is considered an important factor in acceptability of beef because consumers seek meat with certain sensory characteristics. Consumers tend to accept beef that responds to their needs and that provides a high degree of satisfaction (Heldman, 2004). Determining consumer perception is often difficult; as a result studies of consumer acceptability or preference rely on establishing the relationships between the intensity of perceptible attributes and degree of acceptance (Jaeger, Rossiter, Wismer & Harker, 2003).

3.7.1.1 Selection and training of the descriptive sensory panel

Ten (10) panel members were selected from the trained panel of the Agricultural Research Council to participate in the development of the sensory profiles of the selected import beef cuts (Stone & Sidel, 1993:204). These trained panel members were selected on the basis of their experience with tasting various food products (especially meat and other meat products), interest in the project, availability for the duration of the study and good health (Meilgaard *et al.* 2007:150).

It is essential that the panel members must be able to detect differences in the attributes present and their intensities. They must also be able to describe those attributes using verbal descriptors and scaling methods for the different levels of intensity (Meilgaard *et al.* 2007:149). Thorough training was provided to ensure that panellists have a proper understanding of the attributes. The descriptive sensory training sessions were conducted over four consecutive days (two hours a day).

The panellists were also trained to familiarise them with the test procedure (how to evaluate a sample, how many samples to evaluate at a time, interval between evaluating samples and what palate cleanser to use between samples). Their sensitivity and memory was also improved by retraining them in between the different cuts so that they could be able to make precise and consistent sensory judgments (AMSA, 1978).

3.7.1.2 Lexicon development

The panel leader identified sensory attributes that needed to be evaluated; aroma, juiciness tenderness and flavour. The panel leader communicated these attributes to the panel. To create a frame of reference that represents as many of the attribute differences likely to be encountered when evaluating beef, we sourced beef samples that are commercially available (Meilgaard *et al.* 2007:152). The beef samples used were from two age classes (A- age and B-age), three post-mortem aging periods (0 days, 14 days 35 days) and two feeding regimes (pasture vs. grain). Descriptors were identified, a consensus was reached about all the descriptors and definitions and these were compiled into a lexicon by the panel leader. An evaluation form was then developed by the panel leader based on the lexicon. The panel used this specifically developed lexicon for this study in the evaluation of each of the sensory attributes.

3.7.1.3 Scaling and score sheet used for sensory evaluation

It was stated in Meilgaard *et al.* (2007:55) that scaling techniques involve the use of numbers or words to express intensity of a perceived attribute or a reaction to such an attribute. For this study a category scale was utilised during sensory evaluation of samples. A category scale is a method of measurement in which the subject is asked to rate the intensity of a particular stimulus by assigning it a value on a limited numerical scale (Meilgaard *et al.* 2007:56). Category scales are common in descriptive analysis studies as they have the advantage of being easy to use and can cover a number of attributes, as well as up to six samples in a session (Nute, 2002).

The panel was trained on the use of the 8-point category rating scale, where one (1) on the category scale represented the least intense condition and (e.g. extremely bland) and eight (8) represented the most intense condition for a specific sensory attribute (e.g. extremely intense). The trained panel then evaluated the samples according to standardised descriptive sensory evaluation methods as described in (American Standardised Testing Methods, 1996). Instructions on how the different sensory attributes should be evaluated were also provided on the evaluation sheet.

3.7.2 Physical evaluation

Physical evaluation is performed by using equipment which varies in complexity; attributes of meat such as tenderness are often measured by objective methods. The data obtained can be used to reinforce data obtained subjectively through sensory evaluation. (McWilliams, 2012 :71). In this study the two objective tests that were performed are; shear force resistance and thawing/cooking measurements. Shear force measured tenderness of the selected import beef cuts whereas thawing/cooking losses were measured by means of a measuring scale.

3.7.2.1 Shear force resistance

Shear force measurement was used for the objective texture analysis of the meat cuts. Cooked meat samples (which were left to cool down to below 16^0C) were cored into 12.5 mm diameter cylinders parallel to the grain of the meat (see Addendum E Figure 11). These were sheared perpendicular to the fibre direction using a Warner Bratzler shear device mounted on a Universal Instron Machine (Instron 4500, series IX version 5, Massachusetts) (see Addendum E Figure 10). A speed of 200mm.min-1 with a 1kN load cell was applied. Six (6) cores per sample were tested. The reported value in newton (N) represented the peak force measurement of each sample. A high value of shear force is associated with tough meat whereas a lower value is associated with meat that is tender (Destefanis *et al.* 2007).

3.7.2.2 Thawing

The beef steaks that were used for the study were vacuum packed individually in bags and kept frozen. Twenty four hours prior to cooking, the steaks (to be evaluated) were removed from the freezer and placed in a 4^0C refrigerator to allow them to thaw. The mass of each steak contained in a bag with thaw loss was recorded on a cooking data sheet. Once the steak was removed from the bag (placed on a rack), the mass of the bag containing the exudate (remaining thaw loss) was recorded. The exudate was then poured out and the mass of the empty bag was recorded. The formula that was used to calculate thawing loss was as follows:

$$\text{Thaw loss (\%)} = \frac{\text{mass of bag +exudate} - \text{mass bag without exudate}}{\text{mass raw meat + thawing loss+ bag} - \text{mass bag without exudate}} \times 100$$

3.7.2.3 Cooking losses

After cooking, the steak samples were removed from the oven and mass of the steaks together with the pan and rack was recorded. The steaks were removed from the rack of the pan and the mass of the pan plus the rack and drip was recorded. The drip loss (cooking loss) was poured into a glass cylinder, thereafter the mass of the pan and rack together with the residue drip was recorded. The formula that was used to calculate cooking loss was as follows:

$$\text{Cooking loss (\%)} = \frac{\text{Total mass of drip loss X 100}}{\text{Mass of raw meat}}$$

3.8 SAMPLE AND SAMPLING

3.8.1 Unit of analysis

The three selected import beef cuts namely, loin, rump and rib-eye of different age classes, feeding regimes and post-mortem aging periods were used as the unit of analysis for the study. The sample selection, handling, preparation and cooking of the meat as well as the serving procedure will be discussed.

3.8.2 Sample selection for sensory evaluation

The primal cuts (n= 360) of which (n=120) were loin, (n=120) rump and (n=120) rib-eye used in this study were obtained from MEATCO in Namibia, from two different abattoirs, one based in Windhoek and the other one based in Okahanja. The sampling was completed at the abattoirs. An illustration of how the sampling was completed can be seen in (see Addendum D Table D1). These specific beef cuts were selected on the basis of being mostly consumed by the consumer group under discussion (South African consumers of this beef) and being easy to prepare as they can be cooked by dry heat cooking methods.

3.8.3 Handling and storage of beef cuts

The primal cuts were obtained from the carcass post-slaughter. These were labelled accordingly, vacuum packaged and aged post mortem for 55 and 36 days respectively. After the aging process was completed, the samples were frozen and exported in their frozen state to City Deep in Johannesburg where they were also kept in a frozen storage at -21°C. The cuts were then transported in a freezer truck to the Animal Production Institute of the Agricultural Research Council (ARC- API) in Irene to be stored in a -22°C freezer room. The cuts (n=40) to be evaluated each week were sliced into three to four steaks (depending on the size of the primal cuts) measuring 2.5 cm thick by means of a band saw. This was done during the week prior to tasting (see Figure 1- Addendum E). The steaks were re-labelled and vacuum packaged again, sorted according to evaluation days and returned to the freezer (see Addendum E Figure 2). Each day's samples were taken out of the freezer the day before they had to be cooked and left to thaw in a 4ºC cool room overnight (18-24hours) (see Addendum E Figure 3) (AMSA, 1978).

3.8.4 Sample selection for the preparation of meat

Correct sampling requires careful attention. Simple random sampling was utilised to design a block for the order of serving of the samples. This type of sampling is often used when a population is uniform or has similar characteristics as in the case of this study (Walliman, 2009:277). One cut was dealt with at a time. Eight steaks were selected from the group of samples to constitute a day's samples. These samples were not selected in any specific order but a day's samples had to be from different abattoirs (Okahanja or Windhoek) age classes, feeding regimes and aging periods. (See addenda G, H and I).

3.9 DATA COLLECTION: PHASE 1

An experimental design was utilised for this study. This provided the plan and strategy that was used throughout the study. The flow diagram that depicts the experimental procedure is shown in Figure 3.8. Experiments involve taking action and observing the consequence of that action. Experiments are also carried out with the aim of developing a generalised understanding about the problem at hand (Babbie & Mouton, 2001:208). The experimental design is suitable for research projects with limited and well defined concepts. This empirical study followed a highly controlled laboratory experimental design where primary data was collected (Babbie and Mouton, 2001:76).

3.9.1 Pilot study

It was important that consistency be maintained during data collection as it helped elude deviation and variation in the standardised data collection method. To ensure consistency, a pilot study was performed prior to project commencement. During a pilot study, the cooking procedure (physical state of the cut prior to cooking, methods to monitor temperature changes, evaluating doneness and recommended cooking methods) and serving procedure (testing environment, number of sessions per day, size of the sample, order of sample presentation, number of samples per session and serving temperature) are standardised (AMSA, 1978).

3.9.2 Experimental procedure

Phase 1 of the data collection process involved descriptive sensory evaluation. Figure 3.4 presents the flow diagram of the experimental procedure that was followed during sensory evaluation. The sensory evaluation process for each of the cuts took place over 19 days (four (4) consecutive training days and fifteen (15) evaluation days for the first cut. For the second and third cut, the evaluation process was 16 days for each cut, one day training and fifteen evaluation days, so in total 51 days (1-2 hours each day) were used for sensory evaluation. Panel members as measuring instruments are often variable over time and prone to bias, so to validate the taste measurements, it is required that measurements be repeated and enough subjects used so that the results are representative (Meilgaard *et al.* 2007:155).

LOIN | **RIB-EYE** | **RUMP**

Vacuum packaged and aged for 36 and 55 days

↓

Frozen and transported to ARC

↓

Cuts processed into steaks and re- frozen

↓

Thawed at 4°C prior to cooking

↓

DRY HEAT COOKING: BROILING

Time	Specifications	Equipment	Temperature	Steak
20-25 min	Preheat oven for 10 minutes prior to cooking	Oven pan Oven rack Knife Kitchen Scissors Oven Tongs Plates	Broiling at 200°C to internal temperature of 70°C.	2.5 cm

SERVING PROCEDURE				
Holding temperature	**Materials and equipment**	**Sample size**	**Serving temperature**	**Other**
Samples were kept warm at 100°C	81cm² foil squares with 3 digit codes. Electric knives Cutting boards Plates Evaluation form Pencils and erasers	1cm³	60°C	2 samples served at a time with 20 minutes break in between tasting sessions

ATTRIBUTES			
AROMA	JUICINESS	TENDERNESS	FLAVOUR

↓

EATING QUALITY

FIGURE 3.2: FLOW DIAGRAM FOR THE EXPERIMENTAL PROCEDURE FOR PHASE 1

3.9.2.1 Cooking method and time

Eight samples were cooked each day. Each sample that was cooked comprised of three steaks (two steaks were used for sensory evaluation and one steak used for shear force measurement). These steaks were put side by side on the grid of an oven pan and weighed prior to cooking to calculate all the thawing losses (see Addendum E Figures 4 and 5). The samples were then cooked individually according to a standardised dry heat cooking method (grilling) in eight identical Mielé ovens at 200ºC until the muscle to be evaluated (geometrical centre) had reached an internal temperature of 70ºC (AMSA, 1978).

The cooking time varied slightly according to the size of the steaks but ranged between 20-25 minutes. The steaks were first cooked on one side for 10 minutes and then turned (see Figure 6- Addendum E) and cooked for another 10 minutes or until the final temperature (70ºC) was reached The core temperature was measured with a hand model Kane- Mane probe equipped with a t- type thermocouple (see Addendum E Figure 7).

The meat was then removed from the oven and weighed to calculate cooking losses (see Addendum E Figure 7). Two of the steaks were transferred to a warmed up plate and kept warm (allowed to rest) at 100ºC for 5 minutes. The third steak was placed on a side plate and was used for objective texture evaluation. The drip from the pan was poured into a cylinder and left to solidify (which took about 4 hours) after which the amount of fat and stock were measured. When the steaks were ready to be cut (after their resting period) they were removed from the oven and placed on a cutting board.

The steaks were trimmed using an electric knife to remove the fat and the meat on the outermost sides (which is usually overcooked), because the meat to be evaluated lies in the center of the steak. This is illustrated in Figure 3.3.

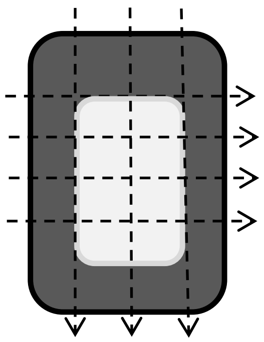


FIGURE 3.3: ILLUSTRATION OF THE CUTTING PROCEDURE FOR SENSORY EVALUATION SAMPLES

The darker shaded part, is meat that was discarded and the lighter shaded part represented the meat that was used for the evaluation. The size of the sample was 1cm^3. The cubes of meat were wrapped individually in aluminium foil squares (with the glossy side inside) marked with 3 digit numbers on the matt side of the foil (see Addendum E Figure 8) (ASTM, 1996). The wrapped samples were placed on a pre-heated side plate and returned to the oven set at 100°C for 2-5 minutes to warm up to a serving temperature of 60°C.

3.9.2.2 Serving procedure for sensory evaluation

Samples were served in pairs on pre heated side plates to maintain ideal serving temperature of 60°C. The pre heated plates were placed on a white tray which was laid with a blank sheet to prevent the plate from moving around. Trained panel members received a lexicon (defining the attributes) and a sensory evaluation form to enable them to evaluate the samples. They also received on the tray a pencil, eraser, glass of water and palate cleanser which for this project was five slices of carrots placed in a small plastic container (see Addendum E Figure 9). The evaluation took place under red light conditions, to prevent the colour of the meat samples from influencing the perception of the panellists. It took between 5-7 minutes for the panel to evaluate the two samples per session. The panel members were then given a 15-20 minute break between sessions to prevent sensory fatigue (ASTM, 1996).

The two data collection phases of the study ran concurrently. Phase 2 involved objective evaluation. Results of objective evaluation of meat tenderness are of great importance in meat research (McWilliams, 2012:52).

3.10 DATA COLLECTION: PHASE 2

A flow diagram of the experimental procedure followed to determine eating quality of beef cuts utilising objective methods is shown in Figure 3.4. In this figure the selected beef cuts, specifications and equipment utilised are indicated. The physical measurement carried out was shear force resistance measurements of cooked beef samples.

3.10.1 Shear force resistance

The cooking method is the same as used for the sensory evaluation samples because these samples were cooked at the same time. The cooked steak was transferred to a cold side plate and put on the trolley and after all the steaks were cooked the trolley was pushed into a 16°C air conditioned room. The steaks were left for 2-3 hours to cool down to a temperature

16°C and below. The procedure followed to measure tenderness of the samples has been explained in section 3.7.2.1

LOIN | **RIB-EYE** | **RUMP**

DRY HEAT COOKING: BROILLING

Time	Specifications	Equipment	Temperature	Steak
20-25 minutes	Preheat oven for 10 minutes prior to cooking	Oven pan Oven rack Knife Kitchen Scissors Oven Tongs Plates	Broiling at 200°C to internal temperature of 70°C.	2.5 cm

Allow steaks to cool to 16°C in a temperature controlled room

Using a coring device, six cores parallel to the grain were cored per steak

SHEAR FORCE measured using the Warner Bratzler shear force device

FIGURE 3.4: FLOW DIAGRAM OF THE EXPERIMENTAL PROCEDURE FOR PHASE 2

3.11 DATA ANALYSIS

The sensory evaluation and objective data collected, was analysed statistically by the Biometry unit of the ARC, where a statistical programme Excel 2010 with add-on software XLSTAT was used (XLSTAT, 2011). The statistical techniques used to analyse the data were; Analysis of Variance (ANOVA) and a multivariate analysis technique, Principal component analysis (PCA). Least significance Difference (LSD) test was applied to examine whether the means from two or more small groups of observation were statistically different or they were about the same. Each of these statistical methods is briefly discussed.

3.11.1 Analysis of Variance (ANOVA)

An ANOVA analysis was used to determine the effects of independent variables (age classes, feeding regime and post- mortem aging) on the dependent variables (sensory attributes: aroma intensity, juiciness, tenderness and typical beef flavour, shear force, cooking and thaw losses).

ANOVA is a very common statistical test applied in descriptive sensory analysis and other sensory tests where more than two products are compared using scaled responses. It provides a sensitive tool for determining whether treatment variables such as changes in ingredient, process or packaging had an effect on sensory properties of products. ANOVA has the ability to compare several means of a number of products at the same time and analyse whether they differ or not for a specific attribute (Lawless & Heymann, 1998: 700-701).

When using ANOVA a ratio of the factor of variance to the error of variance is constructed. If the F ratio is significant for a given factor it means that at least one of the individual comparisons among means is significant for that factor (Lawless & Heymann, 1998:702-703). In this study a one way ANOVA was applied with Fisher's protected t test least significant difference level at 5% level of significance.

3.11.2 Multivariate analysis

Multivariate analysis of variance is a procedure that determines whether significant differences exist between treatments when compared on all dependent variables of interest. Multivariate analysis tests for differences between two or more treatments and unlike ANOVA it evaluates all dependent variables simultaneously. Such analyses are fundamental in sensory studies involving descriptive analysis, where multiple descriptors are used to describe and evaluate a product. Each dependent attribute may first be analysed by one way ANOVA to determine if a difference exists, this will then be followed by multivariate analysis which will assess the influence of all descriptors simultaneously (Lawless & Heymann, 1998:586).

3.11.2.1 Principle Component Analysis (PCA)

PCA is a multivariate statistical technique used to identify the smallest number of latent variables, called 'principal components', which explain the greatest number of observed variability (Meilgaard *et al.* 2007: 360). It is also used to simplify and describe interrelationships among multiple dependent variables and among samples (Lawless & Heymann, 1998: 588). It is able to explain as much as 75-90% of the total variability in a data set consisting of 25-30 variables with as few as 2-3 principal components. PCA analyses the correlation structure of a group of multivariate observations and identifies the axis where maximum variability in data occurs, this axis is thus termed the first principal component. The second principal component lies on the axis where the greatest amount of remaining variability occurs and lies perpendicular to the first principal component (Meilgaard *et. al.*, 2007:360). PCAs were used in this study to illustrate the groupings of the different treatments subject to the sensory attributes and the correlation between attributes and samples.

3.12 RELIABILITY AND VALIDITY

Precision and accuracy are important qualities in research measurement. However there are two technical measures that need to be taken in to account in research, these are; reliability and validity (Babbie & Mouton, 2001:119). These concepts will be discussed briefly as they relate to this study.

3.12.1 Reliability

Reliability is a measure of whether a particular technique applied repeatedly to the same object would yield the same result each time. Reliability is very important for the successful outcome of a project and it is dependent on consistency (Babbie & Mouton, 2001:119). Sensory evaluation is a science of measurement and like any other analytical test procedure it is concerned with precision, accuracy, sensitivity and avoiding false positive results (Meiselman,1993 as cited in Lawless & Heymann,1998:3). In sensory analysis reliability is ensured by isolating the sensory response to factors of interest, minimizing extraneous influences and controlling sample preparation and presentation (Lawless & Heymann, 1998:3-4). In order to achieve reliability in the study the following measures were taken at various points during the data collection process:

It was not possible for the researcher to be present at the abattoir where the sampling was completed, but the abattoir was given strict instructions (by the research team) on how the samples were to be labelled to make it easier for the team to identify them. The samples had to be sliced further into steaks; care was taken in the new labelling and repackaging of samples so that they could be traceable. The researcher was present during this stage and could check that all samples were labelled correctly and that samples were not mixed.

A pilot study was conducted prior to the commencement of the project in order to standardise the techniques that were to be used during sensory and objective evaluation. During this time the cooking and serving procedures were standardised. The measuring instruments (measuring scale and Warner Bratzler Shear force) used for physical evaluation were also calibrated.

One cannot underestimate the need for reliability in an analytical test such as descriptive evaluation. This test relies on 10-20 subjects which is a small number for one to base their recommendation on. In order for the results of this test to be accepted as valid the researcher needs to have confidence in the subjects selected. Such confidence comes from the repeated measures during data collection (Stone & Sidel, 1993: 109).

Panellists were selected from the trained panel of the Agricultural Research Council (ARC) Irene, based on their ability to provide similar responses to food products on repeated occasions, good taste and smell acuity, interest in the project and availability for the duration of the study. The panel went through an extensive and in depth training prior to evaluation of the samples and this is where the researcher stressed the difficulty of sensory evaluation and the need for attention and concentration (Lawless & Heymann, 1998: 112).

The trained panel evaluated the beef samples according to a standardised descriptive sensory evaluation method. The evaluation also took place under red light conditions eliminating any chance that colour/ appearance could have on the perception of the panellists. The sensory analysis laboratory of the ARC is constructed according to the ASTM design guidelines for sensory facilities (ASTM, 1996). The tasting booths were quiet, free from any noise or intrusions and no odours from the food preparation area could be detected from the tasting side which could influence the panel’s perception (Meilgaard *et al.* 2007:33).

3.12.2 Validity

Validity refers to the extent to which an empirical measure adequately reflects the real meaning of the concept under consideration (Babbie and Mouton, 2001:122). It is concerned with the ability of a test procedure to measure what it was designed or intended to measure. The validity of sensory studies depends on accuracy (Greenfield & Southgate, 1992) and on control of various factors with the testing environment. Validity is more difficult to deal with because it is not directly measured. The most general way describe validity is “the degree to which results are consistent with the facts” (Stone & Sidel, 1993: 109).
There are numerous kinds of validity. The kinds of validity applicable to the present study were: construct validity, content validity, face validity and theoretical validity. Each is explained in terms of how they were ensured in this study.

Construct validity is concerned with the meaning of the instrument, what it measures, how and why it operates as it does (Babbie & Mouton, 2001:123) Construct validity is based on statistical procedures and logical relationships among variables (Kumar, 2014:224). It determines the degree to which a theoretical construct is measured accurately by the instrument.
A thorough literature review was used in the identification of the constructs and the lexicon applicable to the study.

Content validity concerns itself with the sampling adequacy or representativeness of the study’s content as an instrument. The measuring device covers a full range of meanings or forms within the concepts being measured (Babbie & Mouton, 2001:123; De Vos, Strydom, Fouche & Delport, 2005:162).
The eating quality was measured through the sensory attributes of aroma, juiciness tenderness and flavour. For sensory evaluation an 8-point standardised category scale was used. For statistical reliability and validity, replications within this research study took place, where each sample was tasted five times over the fifteen day tasting period (Stone & Sidel, 1993:111).

Face validity is a subjective judgment of the operationalisation of a construct and it is based on the logical link between the questions and objectives of the study (Kumar, 2014:223).
The sensory evaluation forms with an 8-point category scale served as measurement for the sensory attributes that were evaluated. Rating the intensity of the different attributes was necessary to give a holistic view of the eating quality of meat. The multiple measurements of

the sensory and objective tests contributed to triangulation of measurements that further enhanced the study's validity.

Theoretical validity seeks to evaluate the validity of the researcher's concepts and the theorised relationships among concepts in context with the phenomena.
To enhance theoretical validity of this study all concepts relating to meat eating quality, sensory quality and physical quality were identified through a thorough literature review. Once the training sessions for sensory evaluation commenced the constructs to be measured were introduced to the panellists. A lexicon was developed for the attributes (constructs) to be evaluated to lessen ambiguity and ensure that correct constructs are being measured by the panellists.

3.13 ETHICS

The proposal of the study was prepared and presented to the Head of department, lecturers and students of the consumer science department. Following this, ethical approval was obtained from the Ethics Committee of the Faculty of Natural and Agricultural Science, University of Pretoria, ethics approval number: EC140114-002 (see Addendum A).

The panellists that were used for the study gave their voluntary consent to participate and were able to exercise free power of choice about participation in the study, and also had the legal capacity to give consent. The researcher protected the rights and welfare of all the subjects and ensured that each person who participated in the study had the right to adequate and informed consent without undue pressure (Lawless & Heymann, 1998:109).

Sensory studies of food products do not create risks above the ordinary risks of daily life. However, panellists were told of all possible risks associated with food products, for example possible allergens. In this study, beef was evaluated and the majority of people do not have adverse reactions to it. A legal document was signed by the meat producers to certify that the beef samples provided were safe for human consumption. The preparation, cooking and presentation of samples were done according to the regulations set out by the ASTM, 1996.

3.14 CONCLUDING SUMMARY

In this chapter the research methodology followed for the execution of the study was outlined. To achieve the main objective of this study, two phases of data collection were employed. The procedures and techniques followed in these two phases were explained in detail. This chapter also gave a thorough indication of how the different sets of data were analysed. Reliability and validity were also discussed, to explain how these two measures were maintained throughout the study. In the next chapter the results obtained from the execution the study are presented and discussed.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The results will be presented in two phases according to how the study was undertaken. In phase 1 descriptive sensory evaluation was employed where human subjects were used to evaluate the meat samples by scoring the intensity of the different attributes. Phase 2 focused on objective evaluation; where calibrated measuring instruments were used to measure the different physical attributes such as thawing losses, cooking losses and shear force analysis.

4.2 DESCRIPTIVE SENSORY ANALYSIS

The aim of sensory evaluation was to determine if there were any significant differences in the scores of the sensory attributes of each beef cut of the various age classes, feeding regimes and post-mortem aging periods. At the beginning of the training sessions there were a number of descriptors identified. After consensus was reached by the panel, these were narrowed down to twelve attributes. Of these twelve attributes, three were tenderness related attributes (first bite, overall tenderness and connective tissue/residue) and juiciness .The other eight attributes were aroma and flavour related such as; typical beef flavour, roasted beef, beef meat, rancid, animal-like, sour and green flavours. The attributes were used to evaluate the different meat samples. The results of the descriptive analysis were analysed statistically using ANOVA.

When presenting and discussing the results, the loin cut will be the first followed by the rib-eye and then the rump. The results of the ANOVA for all tenderness related attributes and juiciness of each cut will be tabulated and discussed. These will be followed by histograms showing the frequency distribution of individual scores over the 8-point scale for a particular attribute. For the flavour and aroma attributes the results of the ANOVA are tabulated and discussed and these are followed by frequency distributions which show how often a specific flavour undertone was perceived by the panellists.

4.2.1 Results of the effect of age/feeding regime on tenderness and juiciness of the loin, rib-eye and rump

Table 4.1 shows the mean values and standard deviations for juiciness and all tenderness related attributes of the loin, rib-eye and rump for the six age and feeding regime groups. For all cuts, juiciness and tenderness related attributes (first bite, muscle fibre and overall tenderness and amount of connective tissue) were affected by both age and feeding regime.

TABLE 4.1: MEAN VALUES AND STANDARD DEVIATIONS FOR JUICINESS AND TENDERNESS RELATED ATTRIBUTES OF THE LOIN, RIB-EYE AND RUMP FOR SIX AGE/FEEDING REGIME GROUPS

CUT				**AGE GROUP**				
LOIN	Attribute	AG	ABG	AF	ABF	B4	B6	*P* value
	Juiciness	4.5^{d}	4.8^{bcd}	4.7^{cd}	4.8^{bc}	5.0^{ab}	5.1^{a}	0.002
	SD	*0.97*	*0.93*	*1.05*	*0.92*	*0.91*	*0.86*	
	First Bite	5.5^{a}	5.6^{a}	5.6^{a}	4.6^{b}	4.5^{b}	4.3^{b}	<0.001
	SD	*1.20*	*1.18*	*1.31*	*1.41*	*1.34*	*1.51*	
	Tenderness	5.5^{a}	5.5^{a}	5.4^{a}	4.6^{b}	4.8^{b}	4.4^{b}	<0.001
	SD	*1.11*	*1.13*	*1.21*	*1.24*	*1.27*	*1.41*	
	Connective tissue	5.2^{a}	5.3^{a}	5.1^{a}	4.3^{b}	4.5^{b}	4.2^{b}	<0.001
	SD	*1.15*	*1.14*	*1.24*	*1.22*	*1.25*	*1.38*	
RIB-EYE								
	Juiciness	4.7^{d}	4.8^{cd}	4.5^{e}	5.0^{bc}	5.1^{b}	5.3^{a}	<0.0001
	SD	*1.05*	*1.07*	*1.05*	*0.96*	*0.88*	*0.86*	
	First Bite	5.5^{a}	5.4^{ab}	5.0^{b}	4.2^{c}	4.3^{c}	4.3^{c}	<0.0001
	SD	*1.36*	*1.25*	*1.40*	*1.43*	*1.36*	*1.46*	
	Tenderness	5.5^{a}	5.6^{a}	5.1^{b}	4.4^{c}	4.5^{c}	4.7^{c}	<0.0001
	SD	*1.20*	*0.99*	*1.12*	*1.22*	*1.09*	*1.31*	
	Connective tissue	5.2^{a}	5.2^{a}	4.8^{b}	4.0^{d}	4.2^{cd}	4.4^{bc}	<0.0001
	SD	*1.22*	*1.05*	*1.21*	*1.24*	*1.13*	*1.31*	
RUMP								
	Juiciness	4.6^{b}	4.6^{b}	4.7^{b}	4.7^{b}	4.8^{ab}	5.0^{a}	0.005
	SD	*1.03*	*0.94*	*0.99*	*0.98*	*0.97*	*0.98*	
	First Bite	*5.4^{a}*	*4.6^{bc}*	*5.0^{ab}*	*4.3^{cd}*	*4.0^{d}*	*4.1^{d}*	<0.0001
	SD	*1.26*	*1.34*	*1.27*	*1.49*	*1.61*	*1.42*	
	Tenderness	5.4^{a}	4.7^{bc}	5.0^{ab}	4.4^{cd}	4.1^{d}	4.2^{d}	<0.0001
	SD	*1.14*	*1.22*	*1.09*	*1.24*	*1.43*	*1.35*	
	Connective tissue	5.1^{a}	4.4^{bc}	4.8^{ab}	4.1^{cd}	3.8^{d}	4.0^{cd}	<0.0001
	SD	*1.15*	*1.23*	*1.13*	*1.24*	*1.39*	*1.31*	

$^{a, b, c, d}$ Means in the same row with different superscripts differ significantly (P<0.05)
SD Standard deviation

4.2.1.1 Juiciness

Table 4.1 shows that here were significant differences in juiciness among the different age/feeding regime groups for all three cuts (p<0.05). It was generally observed that samples from older animals were juicier than those of younger animals for all three cuts.
For the loin cut, AG recorded the lowest score but not significantly different from its free-range counterpart, AF. In the rib-eye, the lowest score of juiciness was recorded in AF, significantly lower than all the groups. Younger age classes recorded lower but similar values in the rump irrespective of feeding regime or age (AF, AG, ABF, ABG) whilst the older free-range groups (B4 and B6) also recorded similar higher values.

4.2.1.2 First bite, tenderness and connective tissue

There were significant differences in all three tenderness related attributes of the different age/ feeding regime group for all cuts (p<0.05) as shown in Table 4.1. Older free-range groups (B6 and B4) and ABF, had tougher meat than the younger animals AG and ABG and AF.
The loin cut had higher scores for all three tenderness attributes for both grain fed groups (AG and ABG) and the younger free-range group (AF) than the older free-range (B4 and B6) and ABF.
The rib-eye recorded the highest tenderness scores for the two grain fed groups; AG and ABG and slightly lower scores (but significant) for the young free-range group (AF). Older animals (B4 and B6 including ABF) had lower scores for tenderness than the young pasture (AF) and both grain fed groups, which agreed with the results recorded for the loin.
Rump steaks were the most tender in the grain-fed group (AG) and young free-range AF, but significantly tougher in the older grain fed and free-range group; ABG and ABF. The oldest free-range groups (B4 and B6) were still the toughest of all the groups.

4.2.2 Results of the effect of post-mortem aging on tenderness and juiciness of the loin, rib-eye and rump

Mean values and standard deviations for juiciness and tenderness related attributes of the loin, rib-eye and rump for 2 post-mortem aging periods are presented in Table 4.2. There was no significant difference in juiciness or tenderness related attributes found between the 36 days aged and 55 days aged cuts, except that the panel recorded lower scores of connective tissue in loin samples aged for 55 days compared to the samples aged for 36 days.

TABLE 4.2: MEAN VALUES AND STANDARD DEVIATIONS FOR JUICINESS AND TENDERNESS RELATED ATTRIBUTES OF THE LOIN, RIB-EYE AND RUMP FOR 2 POST-MORTEM AGING TIMES

CUT	AGING PERIOD			
LOIN	Attribute	36 days	55 days	*P* value
	First Bite	4.9	5.1	0.116
	SD	*1.46*	*1.40*	
	Tender	4.9	5.1	0.063
	SD	*1.31*	*1.30*	
	Connective	4.6	4.9	0.029
	SD	*1.30*	*1.30*	
	Juiciness	4.8	4.8	0.464
	SD	*1.0*	*1.0*	
RIB-EYE				
	First Bite	4.7	4.9	0.123
	SD	*1.49*	*1.47*	
	Tender	4.9	5.0	0.152
	SD	*1.24*	*1.26*	
	Connective	4.6	4.7	0.281
	SD	*1.24*	*1.31*	
	Juiciness	4.9	4.9	0.819
	SD	*0.99*	*1.03*	
RUMP				
	First Bite	4.5	4.6	0.342
	SD	*1.47*	*1.51*	
	Tender	4.6	4.7	0.422
	SD	*1.33*	*1.34*	
	Connective	4.3	4.4	0.388
	SD	*1.31*	*1.34*	
	Juiciness	4.8	4.7	0.199
	SD	*0.98*	*1.00*	

[a, b, c, d] ***Means for attributes with P values < 0.05 were considered significantly different***
SD Standard deviation

4.2.3 Histograms of tenderness scores

Figures 4.1, 4.2 and 4.3 depict histograms of tenderness scores (1-8) showing the frequency of scores recorded by panellists in each age category. The results from the histograms were in line with the differences among groups indicated by mean tenderness values in Table 4.1.

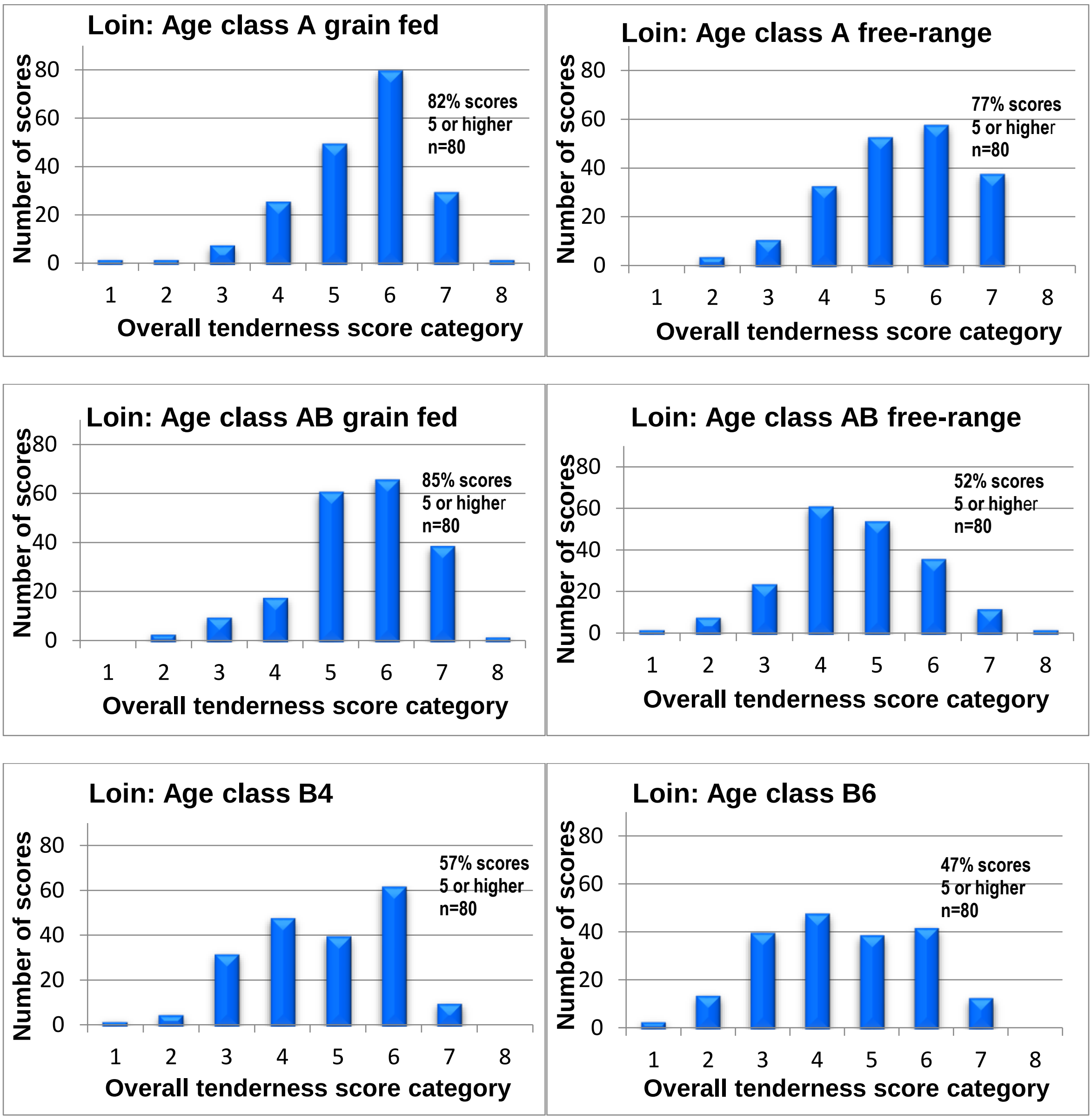


FIGURE 4.1: FREQUENCY DISTRIBUTIONS FOR OVERALL TENDERNESS SCORES OF THE LOIN CUT FOR SIX AGE/FEEDING REGIME GROUPS

For the loin cut, between 82 to 85% of the scores were between 5 and 7 (slightly tender to very tender) for the two grain fed groups (A and AB). These were followed by the young free-range group (AF) which had 77% of its scores in the 5- 7 region. This pattern is in contrast to the older free-range groups (B4 and B6), and ABG, where only between 47 to 57% of their scores were between 5 and 7. It was also noted that B4 had more scores of 6 than ABF and B6. Other tenderness attributes (first bite and connective tissue residue) followed the same pattern but their charts are not displayed.

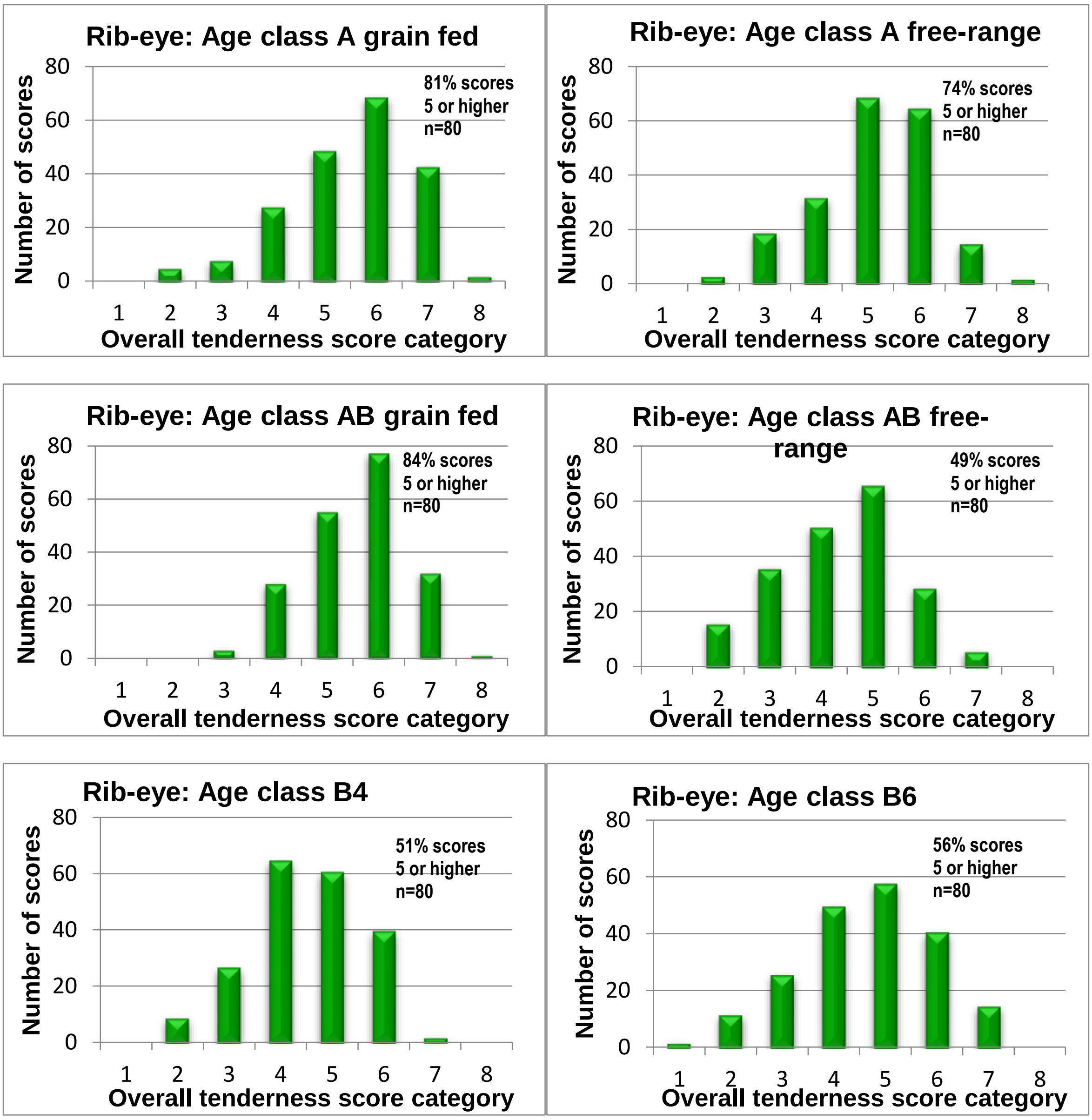


FIGURE 4.2: FREQUENCY DISTRIBUTIONS FOR OVERALL TENDERNESS SCORES OF THE RIB-EYE CUT FOR SIX AGE/FEEDING REGIME GROUPS

In the rib-eye, the same pattern as that of the loin was observed, the two grain fed groups A, AB had between 81 and 84% of their scores between 5 and 7. These were followed by the younger free-range group which had 74% of its scores between 5 and 7. The free-range ABF, B4 and B6 recoded between 49-56% of their scores in the 5 to 7 region. In addition, slightly more scores of 5, and less of 6 and 7 were recorded in AF in contrast to the two grain fed groups AG and ABG which recorded more scores of 6 and 7, hence the slightly lower percentage scores of 5 to 7in AF compared to AG and ABG (74% vs. 81 and 85%). This observation correlates with the mean values of Table 4.1 where AF also had lower mean tenderness scores compared with AG and ABG. It was also further noted that B6 had slightly more scores in categories 5 to 7 than B4 and the free-range AB.

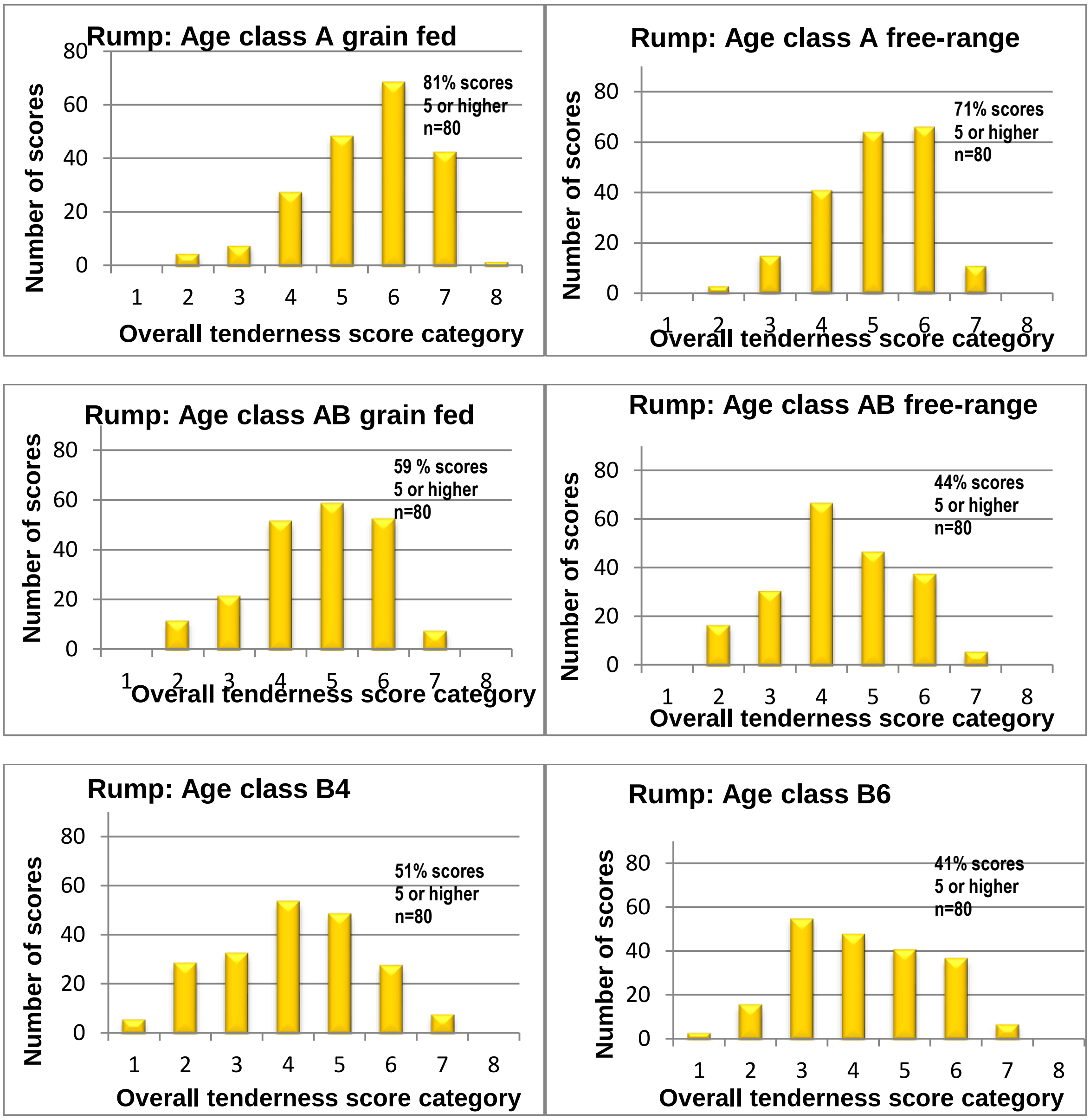


FIGURE 4.3: FREQUENCY DISTRIBUTIONS FOR OVERALL TENDERNESS SCORES (1-8) OF THE RUMP CUT OF FOR SIX AGE/FEEDING REGIME GROUPS

The rump showed higher percentages (71% and 81%) of scores of 5 and higher for both A groups (although the grain fed A group recorded more scores of 6 and 7 than the free-range A group) compared to the other 4 older groups. Both AB groups had lower average tenderness scores (Table 4.1) than their younger counter parts and correspondingly showed less percentages (44% to 59%) of scores of 5 and higher. However, the grain fed AB group had more scores of between 5 and 7 than the free-range AB group. Although B4 also had lower scores of 5 and higher, ABF and B6 were the groups that recorded the lowest percentages (41 and 44%) of scores of 5 and higher. All the other tenderness related attributes followed the same trend but they have not been shown.

4.2.4 Discussion of the effects of the different variables on juiciness and tenderness related attributes

This section discusses the effect of the different variables namely; age classes, feeding regime and post-mortem aging on the sensory attributes of meat that were identified and evaluated.

4.2.4.1 The effect of age on juiciness and tenderness related attributes

In all three cuts the B4 and B6 samples scored the highest for juiciness. The high scores of juiciness in older animals can be attributed to more mastication that is needed for samples from older animals due to increased cross-linking of collagen with increased age. More saliva is thus released increasing perceived sustained juiciness (Schönfeldt & Strydom, 2011a). Another possible explanation that could not be verified in this study is that younger animals often have little intramuscular fat which leads to a dry sensation in the mouth. Older animals on the other hand tend to have more fat which has a stimulatory effect on salivation thus resulting in meat from older animals being perceived as juicier than meat from younger animals (Lawrie & Ledward, 2006:302).

The results showed that the younger and particularly grain fed animals (AG, AF and ABG) were perceived to be more tender than the older free-range groups (B4 and B6 and ABF). The differences in tenderness of meat can be attributed to a decrease in collagen solubility and tenderness as the animal ages (Li *et al.* 2007;Taylor, 2004; Weston, Rodgers , Pas, & Althen, 2002; Juárez *et al.* 2012). As the animal ages the collagen concentration in the skeletal muscle remains the same, this indicates that the changes in tenderness are related to collagen maturity as there is less collagen synthesis and turnover which allows more time for crosslinks to occur (Kerth, 2013; Weston *et al.* 2002).

Schönfeldt and Strydom (2011b) also found that that age did not have any effect on collagen content but it was the solubility of collagen of both low and high connective tissue muscles that showed dependence on age. It was concluded in their study that tenderness and collagen solubility tend to decrease significantly with age irrespective of the muscle. Although these authors found and observed decline in tenderness as animal maturity increased, Warren, Scollan, Nute, Hughes, Wood and Richardson (2008); Powell (1991) found no significant differences or any decline in tenderness as the age of the animal increases.

4.2.4.2 The effect of feeding regime on juiciness and tenderness related attributes

In this study meat from grain fed animals was perceived as less juicy than that from free-range animals. Lawrie and Ledward (2006) suggested that free-range meat comes from older animals with higher amount of muscle fat which tends to have a stimulatory effect on salivation that copuld be perceived as juiciness. Other studies reported had no effect of feeding regime on juiciness of meat (Garmyn, Hilton, Mateescu & VanOverbeke, 2010; Jiang *et al.* 2010; Warren *et al.,* 2008; Hoving-Bolink *et al.*, 1999).

The effect of feeding regime on tenderness was also evident where the grain fed groups (AG and ABG) were perceived to be more tender than the free-range animals. It is known that grazing on pasture is associated with constant movement of the animals, which results in these animals working their muscles more than their grain fed counterparts and could be the reason why the meat from these animals is often perceived as tough (Dufek *et al.* 2008). Added to this animals fed on grain often reach their slaughter weight more rapidly than their grass fed counterparts and rapid growth over the lifetime of an animal is often associated with meat that is more tender and palatable (Thompson, 2002).

It has also been observed that high energy diets do not necessarily affect collagen content, but they tend to produce meat with high collagen solubility and intramuscular fat which is perceived as tender and juicy by the consumers (Silva, Rego, Simoes, & Rosa, 2010). This suggestion of higher fat in grain fed animals contradicts the previous statement that meat from older grass-fed animals has higher muscle fat (Lawrie & Ledward, 2006). Muscle fat was not analysed in this study and therefore no evidence can be given for the one or the other suggestion.

4.2.4.3 The effect of post-mortem aging on juiciness and tenderness related attributes

Juiciness scores did not change from 36 to 55 days aging for any of the cuts. This is in agreement with reports by Brewer and Novakofski (2008); Jeremiah and Gibson (2003) who observed that ageing (14-28 days) had no effect on juiciness. However a report by Monson, *et al.* (2005), recorded a decrease in juiciness scores from 14 to 35 days which they attributed to the weakening of muscle structure during aging and the subsequent higher losses of liquid during cooking.

No significant differences were found in tenderness related attributes between the 36 and 55 days aged meat samples. This, however, does not imply that aging does not improve tenderness, but it must be noted that most of the improvement with aging occurs in the first 7-10 days with very minor improvements developing with further storage (Brewer & Novakofski, 2008). Extended aging lowered the variation in quality among different breed groups and among individual animals within breed groups (Brewer & Novakofski, 2008). This study had a mix of breeds and types and prolonged aging would have levelled out potential differences between the groups hence the lack of significant difference between the 36 and 55 days aged samples. In this study, it can be concluded that any changes in the perceptions of tenderness or juiciness have probably taken place before 36 days and that no significant changes occurred after that. The long aging period could however not overcome the differences due to age, since collagen is not changed by prolonged aging (Jeremiah & Martin, 1981).

4.2.5 Results of the effect of age/feeding regime on aroma and flavour intensity and other flavour undertones of the loin, rib-eye and rump

Table 4.3 shows the mean values and standard deviations for aroma and flavour intensity and other flavour undertones of the loin, rib-eye and rump for the six age and feeding regime groups. For all cuts aroma and flavour intensity and other flavour undertones were affected by both age and feeding regime.

4.2.5.1 Aroma

The intensity of aroma in the loin cut showed a very small but significant difference among age classes/feeding regime. ABF and ABG groups scored highest for aroma compared to the other groups. There were however no significant differences in aroma intensities for the rump and rib-eye cuts. Some of the panellists described the aroma that they perceived as beefy, roasted or browned, aroma which are associated with cooked red meats.

4.2.5.2 Beef flavour intensity

Beef flavour differed significantly in the loin cut. The two grain fed groups (AG and ABG) had significantly higher beef flavour intensities compared to the free-range groups AF, ABF, B4 and B6. The rib-eye cut followed the same trend as the loin with the grain fed groups having higher intensities for beef flavour compared to the free-range groups. In the rump the differences between the groups were insignificant and no specific pattern was observed.

4.2.5.3 Roasted flavour

Higher intensities of roasted beef flavour were recorded in the grain fed groups AG, ABG and younger pasture group, AF, than in the older pasture groups ABF, B4 and B6 in the loin cut. In the rib-eye cut the same pattern as in the loin cut was observed, where the groups AG, ABG and AF separated from the older groups ABF, B4 and B6 due to higher intensities in roasted flavour. In the rump cut a similar trend was followed as in the loin and rib-eye cuts where the grain fed groups together with the younger free-range group separated from the older free-range groups.

4.2.5.4 Beef meat flavour

There was no significant difference in the intensity of livery flavour between the different groups in the loin cut. In the rib-eye cut the grain fed groups, AG and ABG, and the younger free-range groups, AF, recorded higher scores of livery flavour than B4. In the rump cut, ABG recorded higher scores for livery flavour than ABF and B4, while AF also scored higher than B4.

4.2.5.5 Rancid flavour

The taste panel tended to perceive rancid flavours less often in samples of grain fed (AG and ABG) and young free-range animals (AF) than in older free-range animals. In the loin cut however, AG recorded significantly lower mean scores than all the other groups, while the mean scores of ABG and AF were lower than those of B4, B6 and ABF. For the rib-eye, AF recorded the lowest mean score for rancidity while AG, ABG, B4 and B6 recorded significantly higher scores than AF. In the rump the same pattern was observed, where AF scored significantly lower than all the groups except AG. AG also scored lower than ABG and ABF.

4.2.5.6 Animal-like flavours

The loin cut showed a distinct separation between the groups. The grain fed groups (AG and ABG) and younger free-range group (AF) had lower intensities of animal-like flavours compared to ABF and the older pasture groups (B4 and B6). The rib-eye and rump followed the same trend as the loin with AF recording the lowest mean score for animal-like flavour intensity in both cuts.

TABLE 4.3: MEAN VALUES AND STANDARD DEVIATIONS FOR AROMA, BEFF FLAVOUR INTENSITY AND OTHER FLAVOUR UNDERTONES OF THE LOIN, RIB-EYE AND RUMP FOR SIX AGE/FEEDING REGIME GROUPS

CUT		AGE GROUP						
LOIN	ATTRIBUTE	AG	ABG	AF	ABF	B4	B6	*P* value
	Aroma	5.1^{bc}	5.3^{a}	5.2^{abc}	5.3^{ab}	5.1^{bc}	5.0^{c}	0.038
	SD	*0.98*	*0.98*	*0.95*	*1.03*	*1.04*	*1.02*	
	Beef flavour intensity	5.1^{b}	5.3^{a}	5.0^{bc}	4.9^{c}	4.9^{bc}	4.9^{c}	<0.001
	SD	*0.76*	*0.80*	*0.79*	*0.86*	*0.78*	*0.83*	
	Roasted	2.7^{a}	2.8^{a}	2.8^{a}	2.1^{b}	2.3^{b}	2.1^{b}	<0.001
	SD	*1.70*	*1.83*	*1.76*	*1.49*	*1.58*	*1.46*	
	Beef meat	2.8	2.8	2.7	2.9	2.7	2.9	0.384
	SD	*1.31*	*1.36*	*1.36*	*1.47*	*1.42*	*1.49*	
	Rancid	1.2^{d}	1.3^{bcd}	1.3^{cd}	1.5^{a}	1.5^{ab}	1.4^{abc}	0.011
	SD	*0.58*	*0.86*	*0.80*	*1.14*	*1.05*	*0.91*	
	Animal-like	1.4^{b}	1.6^{b}	1.5^{b}	2.0^{a}	2.0^{a}	1.9^{a}	<0.001
	SD	*0.97*	*1.05*	*1.02*	*1.39*	*1.40*	*1.30*	
	Sour	*3.1^{a}*	*3.2^{a}*	*2.9^{ab}*	*2.8^{b}*	*2.7^{b}*	*2.7^{b}*	*0.003*
	SD	*1.29*	*1.33*	*1.42*	*1.29*	*1.26*	*1.34*	
	Green	*1.3^{b}*	*1.4^{b}*	*1.3^{b}*	*1.8^{a}*	*1.6^{a}*	*1.7^{a}*	*<0.001*
	SD	*0.71*	*0.84*	*0.79*	*1.30*	*1.13*	*1.10*	
RIB-EYE								
	Aroma	*5.5^{a}*	*5.4^{ab}*	*5.3^{b}*	*5.4^{ab}*	*5.3^{ab}*	*5.5^{ab}*	*0.205*
	SD	*0.90*	*0.97*	*0.89*	*0.87*	*0.86*	*0.91*	
	Beef flavour intensity	*5.2^{a}*	*5.2^{a}*	*5.0^{b}*	*5.0^{b}*	*5.0^{b}*	*5.0^{b}*	*0.0006*
	SD	*0.89*	*0.83*	*0.87*	*0.82*	*0.78*	*0.88*	
	Roasted	*2.4^{a}*	*2.5^{a}*	*2.5^{a}*	*1.9^{b}*	*2.0^{b}*	*2.0^{b}*	*0.0005*
	SD	*1.80*	*1.86*	*1.77*	*1.55*	*1.65*	*1.60*	
	Beef meat	*3.9^{a}*	*3.8^{a}*	*3.8^{a}*	*3.8^{ab}*	*3.4^{b}*	*3.7^{ab}*	*0.075*
	SD	*1.61*	*1.58*	*1.62*	*1.63*	*1.64*	*1.76*	
	Rancid	*2.3^{bcd}*	*2.5^{abc}*	*1.9^{d}*	*2.3^{cd}*	*2.6^{ab}*	*2.9^{a}*	*0.0002*
	SD	*1.71*	*1.80*	*1.55*	*1.68*	*1.85*	*1.96*	
	Animal-like	*2.2^{b}*	*2.2^{b}*	*1.8^{c}*	*2.6^{a}*	*2.4^{ab}*	*2.6^{a}*	*0.0001*
	SD	*1.57*	*1.67*	*1.29*	*1.79*	*1.69*	*1.89*	
	Sour	*3.4^{a}*	*3.4^{a}*	*3.4^{a}*	*3.3^{a}*	*3.1^{ab}*	*2.9^{b}*	*0.013*
	SD	*1.69*	*1.61*	*1.71*	*1.60*	*1.64*	*1.65*	
	Green	*1.9^{c}*	*2.1^{c}*	*2.0^{c}*	*2.6^{b}*	*3.0^{a}*	*3.0^{ab}*	*<0.0001*
	SD	*1.48*	*1.60*	*1.46*	*1.64*	*1.85*	*1.89*	
RUMP								
	Aroma	*5.4^{a}*	*5.4^{a}*	*5.3^{a}*	*5.4^{a}*	*5.5^{a}*	*5.4^{a}*	*0.744*
	SD	*0.87*	*0.79*	*0.86*	*0.88*	*0.83*	*0.90*	
	Beef flavour intensity	*5.2^{a}*	*5.1^{a}*	*5.1^{a}*	*4.9^{b}*	*5.0^{ab}*	*5.1^{a}*	*0.098*
	SD	*0.81*	*0.84*	*0.85*	*0.84*	*0.87*	*0.83*	
	Roasted	*3.4^{a}*	*3.0^{abc}*	*3.2^{ab}*	*2.6^{d}*	*2.8^{cd}*	*3.0^{bc}*	*0.0003*
	SD	*1.74*	*1.78*	*1.76*	*1.73*	*1.81*	*1.83*	
	Beef meat	*3.5^{abc}*	*3.8^{a}*	*3.7^{ab}*	*3.4^{c}*	*3.4^{bc}*	*3.6^{abc}*	*0.103*
	SD	*1.58*	*1.51*	*1.44*	*1.68*	*1.64*	*1.60*	
	Rancid	1.6^{bc}	1.9^{a}	1.5^{c}	2.0^{a}	1.9^{ab}	1.9^{ab}	0.003
	SD	*1.29*	*1.52*	*1.23*	*1.57*	*1.48*	*1.46*	
	Animal-like	2.3^{cd}	2.5^{bc}	2.1^{d}	2.9^{a}	2.9^{a}	2.9^{ab}	<0.0001
	SD	*1.55*	*1.67*	*1.45*	*1.81*	*1.77*	*1.73*	
	Sour	4.1^{a}	4.1^{ab}	3.9^{abc}	3.7^{bc}	3.9^{abc}	3.7^{c}	0.125
	SD	*1.49*	*1.38*	*1.51*	*1.44*	*1.43*	*1.35*	
	Green	1.6^{b}	2.0^{a}	1.6^{b}	2.3^{a}	2.3^{a}	2.2^{a}	<0.0001
	SD	*1.16*	*1.50*	*1.17*	*1.61*	*1.61*	*1.52*	

^{a,b,c,d} Means in the same row with different superscripts different significantly (P<0.05)
SD Standard deviation

4.2.5.7 Sour flavour

In the loin, the two grain fed groups (AG and ABG) recorded higher scores for sour flavour than the ABF and the two older free-range groups (B4 and B6). For the rib-eye, only B6 scored lower than all the other groups except for B4. In the rump, the same pattern as the loin and rib-eye was followed but only AG and ABF scored higher than ABF and B6.

4.2.5.8 Green flavour

In the loin cut, green flavour was more pronounced in the older free-range groups (B4 and B6) and ABF than in the grain fed (AG and ABG) and younger free-range (AF) groups. In the rib-eye and rump, a similar trend was observed. However, in the rib-eye ABF also scored lower than B4.

4.2.6 Results of the effect of post-mortem aging on aroma and flavour intensity and other flavour undertones of the loin, rib-eye and rump

In Table 4.4 the mean values for the effect of post-mortem aging on aroma intensity, typical beef flavour and other flavour undertones of the loin, rib-eye and rump are presented. There were no significant differences for the loin cut in the panel’s perceptions of flavour undertones of 36 and 55 days aged samples. In the rib-eye cut, beef flavour recorded a higher score for 55 days aged samples than for 36 days aged samples. In the rump, animal-like flavour undertone was scored higher in 55 days aged sample compared with 36 days aged sample. However, the lack of a general pattern suggests that aging between 36 and 55 days did not affect the panellists’ flavour perception of any of the cuts.

TABLE 4.4: MEAN VALUES AND STANDARD DEVIATIONS FOR AROMA, BEEF FLAVOUR INTENSITY AND OTHER FLAVOUR UNDERTONES OF THE LOIN, RIB-EYE AND RUMP FOR THE TWO POST-MORTEM AGING PERIODS

CUT		**AGING PERIOD**		
LOIN	**ATTRIBUTE**	**36 days**	**55 days**	***P* value**
	Aroma	5.1	5.2	0.079
	SD	*1.02*	*1.04*	
	Beef Flavour intensity	5.0	5.0	0.485
	SD	*0.8*	*0.8*	
	Roasted	2.5	2.5	0.847
	SD	*1.66*	*1.68*	
	Beef meat	2.7	2.8	0.154
	SD	*1.38*	*1.43*	
	Rancid	1.4	1.4	0.955
	SD	*0.9*	*0.9*	
	Animal-like	1.7	1.7	0.760
	SD	*1.20*	*1.25*	
	Sour	2.8	3.0	0.164
	SD	*1.36*	*1.30*	
	Green	1.5	1.5	0.726
	SD	*1.0*	*1.0*	
RIB-EYE				
	Aroma	5.4	5.4	0.557
	SD	*0.91*	*0.89*	
	Beef Flavour intensity	5.0	5.1	0.005
	SD	*0.87*	*0.83*	
	Roasted	2.2	2.2	0.686
	SD	*1.70*	*1.75*	
	Beef meat	3.8	3.7	0.712
	SD	*1.62*	*1.66*	
	Rancid	2.4	2.4	0.880
	SD	*1.77*	*1.80*	
	Animal-like	2.2	2.4	0.184
	SD	*1.65*	*1.71*	
	Sour	3.2	3.3	0.831
	SD	*1.64*	*1.68*	
	Green	2.4	2.4	0.957
	SD	*1.74*	*1.72*	
RUMP				
	Aroma	5.4	5.4	0.150
	SD	0.83	0.87	
	Beef Flavour intensity	5.1	5.0	0.458
	SD	*0.84*	*0.85*	
	Roasted	3.0	3.0	0.420
	SD	*1.77*	*1.81*	
	Beef meat	3.5	3.6	0.615
	SD	*1.58*	*1.59*	
	Rancid	1.8	1.8	0.366
	SD	*1.41*	*1.47*	
	Animal-like	2.5	2.8	0.032
	SD	*1.67*	*1.72*	
	Sour	3.9	3.9	0.603
	SD	*1.40*	*1.47*	
	Green	3.9	3.9	0.603
	SD	*1.40*	*1.47*	

[a, b, c, d] ***Means for attributes with P values < 0.05 were considered significantly different***
SD ***Standard deviation***

4.2.7 Frequency of the scores of aroma and flavour intensity and other flavour undertones of the loin, rib-eye and rump

Figures 4.4, 4.5 and 4.6 illustrate how frequently a specific flavour undertone was detected in samples of each treatment group. Whenever a particular flavour undertone was awarded a score of 2 or more by a panellist, it was regarded as "detected". The results of the frequency graphs corresponded with the differences among groups indicated by the mean flavour values in Table 4.3.

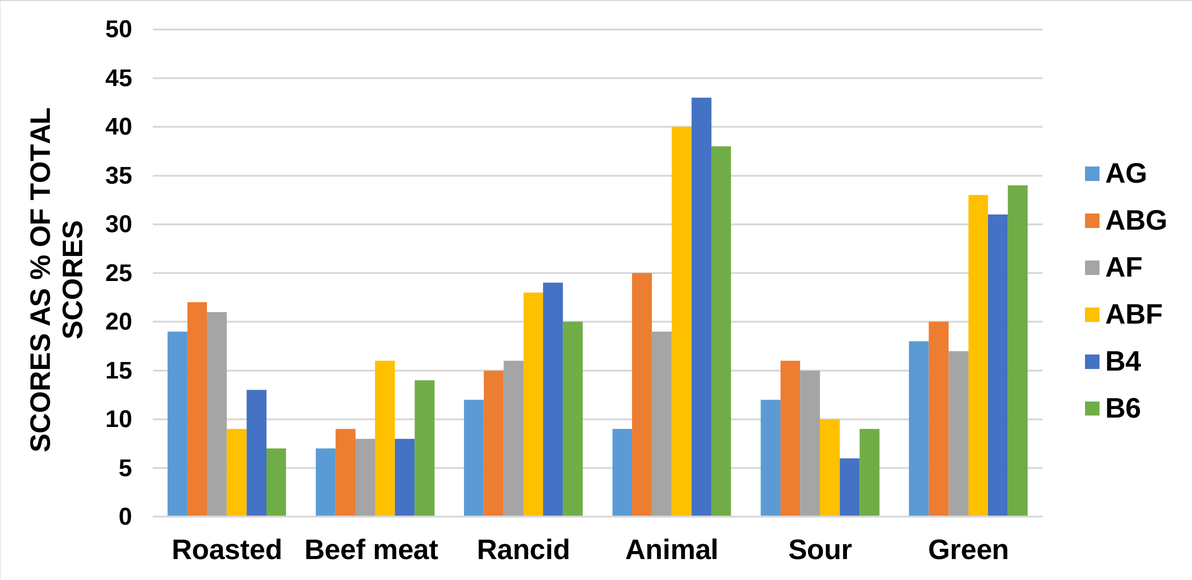


FIGURE 4.4: FREQUENCY OF DETECTING DIFFERENT FLAVOUR UNDERTONES OF LOINS OF SIX AGE CLASSES AND/OR FEEDING REGIMES (% OF TOTAL SCORES)

In the loin cut, the frequency of detecting roasted flavours was higher in the groups AG, ABG and AF than in the older free-range animals; ABF, B4 and B6. The reverse was true for the flavours; beef meat (except for B4), rancid, animal-like and green which were frequently detected in the older free-range animals; ABF, B4 and B6 than in the younger and grain fed groups; AG, AF and ABG.

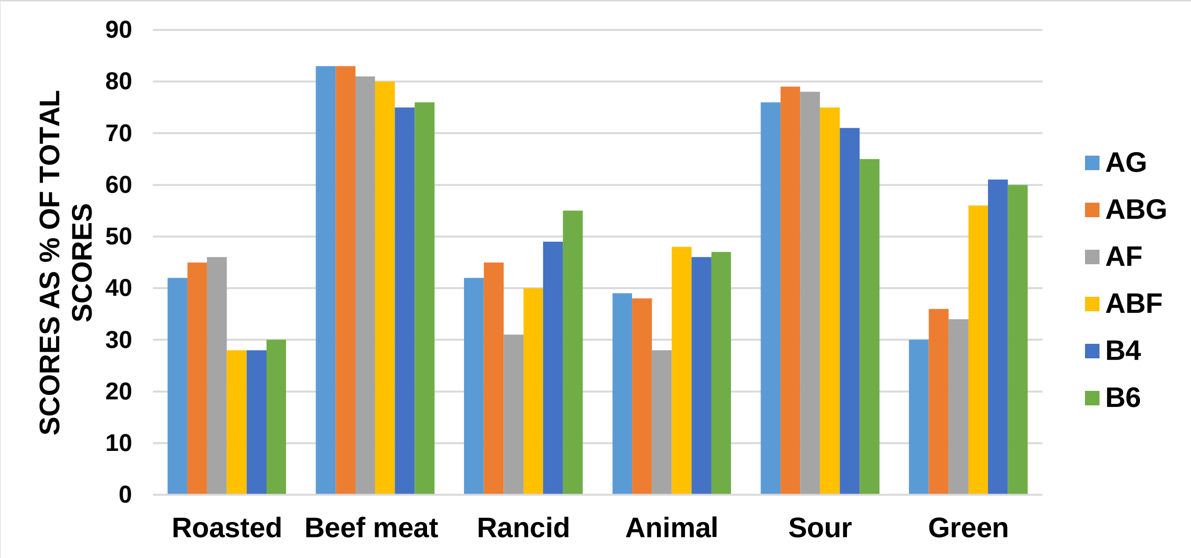


FIGURE 4.5: FREQUENCY OF DETECTING DIFFERENT FLAVOUR UNDERTONES OF RIB-EYES OF SIX AGE CLASSES AND/OR FEEDING REGIMES (% OF TOTAL SCORES)

In the rib-eye cut the same trend was observed, where the frequency of detecting roasted flavours was more in the AG, ABG and AF groups than in the older free-range animals; ABF, B4 and B6. A similar pattern was found with sourness although the contrast between the young and old groups was not as obvious. The flavours rancid, animal-like and green were experienced more in the older free-range groups than in the younger groups. Beef meat flavour tended to be recorded slightly more often in the younger and grain fed groups than in the older free-range groups

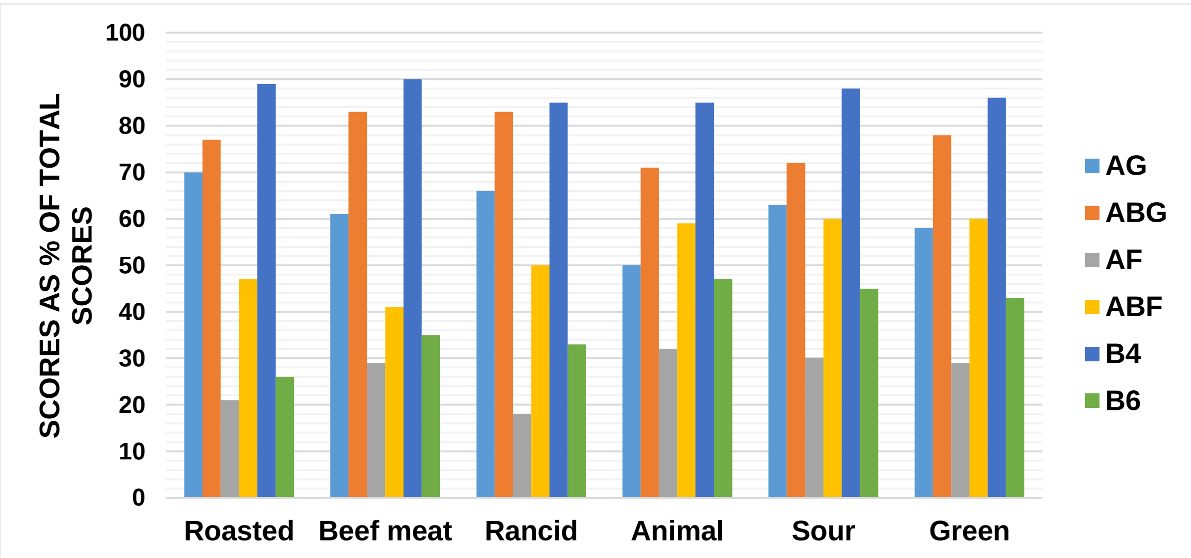


FIGURE 4.6: FREQUENCY OF DETECTING DIFFERENT FLAVOUR UNDERTONES OF RUMPS OF SIX AGE CLASSES AND/OR FEEDING REGIMES (% OF TOTAL SCORES)

In the rump cut, roasted, beef meat and sour flavours tended to be detected more in the younger animal groups than in the older free-range groups. However, the flavours, rancid (except for ABG), animal-like and green flavours were detected more in the older free-range groups than in the younger groups.

4.2.8 Discussion of the effects of the different variables on the flavour attributes

In this section we will discuss the effect of the different variables namely; age classes, feeding regime and post-mortem aging on the aroma and flavour attributes of meat that were identified and evaluated.

4.2.8.1 Effect of age on flavour and aroma

These results indicate that beef flavour intensity declined with age of animal for all cuts. This result is similar to that of Schönfeldt and Strydom (2011a) who also found flavour intensity was the main discriminant of the three age classes that they studied and that it declined with age. They attributed this to changes in amino acid, protein and nucleotide metabolism that occurs with increased age (Smulders, 1991) and the decrease in flavour when maturity of the lean tissue increases (Moloney, Mooney, Kerry & Troy, 2001). In contrast Sink (1979) reported that age affects the "water-soluble, meaty"' aspect more than the "lipid-soluble, species-specific" flavour.

4.2.8.2 Effect of feeding regime on flavour and aroma

In this study flavours like roasted, beef meat and sour were more pronounced in the grain fed and younger animals than in the older free-range animals. In contrast, flavours like, animal, green and rancid were more pronounced in the older free-range animals than in the younger and grain fed animals. The difference in flavour between grass and grain fed samples could be related to changes in their lipid deposition and fatty acid composition (Calkins & Hodgen, 2007). In grain fed diets the most prevalent fatty acids are oleic and linoleic, whereas grass-fed diets have high concentrations of alpha-linolenic and other n-3 polyunsaturated fatty acids (Vasta & Priolo, 2006; Enser, Hallett, Hewitt, Fursey, Wood, & Harrington, 1998). High levels of linolenic acid impart flavours characterized as grassy and fishy, while oleic and linoleic acid impart flavours described as meaty or typical beef flavour (Wood *et al.* 2003).

Roasted or caramelised flavours are typical of meat from grain fed animals (Maughan *et al.* 2012; Melton, 1990). In contrast to this study, Calkins and Hodgen (2007); Nuernberg, Dannenberger, Nuernberg, Ender, Voigi, Scollan, Wood, Nute, and Richardson (2005) found that meat from grass-fed cattle are not characterised by rancid flavours, due to higher concentrations of vitamin E in grass based diets that support the oxidative stability better in comparison with meat from grain fed animals.

Aging meat in vacuum limits oxidation by inhibiting formation of free radicals which would interact with flavour constituents to alter the flavour of meat (Spanier *et al.* 1997). Thus it is unlikely that presence of rancid flavours in this study can be attributed to products of oxidation. It is possible that the presence of rancid flavours in free-range meat in this study could have been due to a lack of a descriptive term for a particular 'off-flavour' that were perceived in this meat by the panellists.

According to Macleod (1994), the presence of sour flavour in meat is a result of coupling of amino acids with organic acids. There is a possibility that the sour flavour of grain fed cattle was due to higher muscle energy levels which produced more lactic acid during rigor mortis to produce more acid like flavour undertones than in free-range cattle.

Animal-like or 'barny', green or 'grassy' and livery flavours are flavours that are usually associated with grass fed meat (Maughan, *et al.* 2012; Wadhwani, Murdia & Cornforth, 2010; Wadhwani, 2008). In the beef flavour lexicon that was developed by (Maughan *et al.* 2012), terms associated with positive attributes are; brothy, umami, roast, beef, browned, fatty and salty. Terms associated with negative attributes are; oxidized, bitter, barny, gamey, grassy, livery, metallic and astringent. The same study also revealed that meat from grass fed animals had higher intensities for barny, bitter and gamey which agrees with our results. It can be concluded that meat from steers that are fed on a high energy maize based diets often have a more desirable or intense beefy flavour in contrast to those that were fed on grass (Imafidon & Spanier, 1994).

4.2.8.3 Effect of post-mortem aging on aroma and flavour

It was found that, except for the overall beef flavour of rib-eye there were no significant differences in flavour between the 36 days and 55 days aged samples. This does not imply that aging has no effect on flavour since the presence of flavours such as animal, livery, sour and rancid are typically associated with prolonged aging (Li, Babol, Bredie, Nielsen, Tománková & Lundström, 2014; Gorraiz *et al.* 2002). However, since both aging periods were fairly long the development of flavour undertones may have been completed by 36 days and therefore showed no changes during further aging. Brewer and Novakofski (2008) noted that the majority of the changes in meat during aging occur in the first seven days. After that any alteration in flavour, occur at a slower rate and then reaches stationary stage where continued aging does not improve the product further (Jiang *et al.* 2010).

4.3 RESULTS AND DISCUSSION OF THE EFFECTS OF AGE/FEEDING REGIME AND POST-MORTEM AGING ON PHYSICAL QUALITY CHARACTERISTICS OF THE LOIN, RIB-EYE AND RUMP

The aim of objective evaluation was to measure and compare the cooking loss, thawing loss and shear force of the different age classes, feeding regimes and post-mortem aging groups. All these characteristics were analysed statistically using ANOVA.

4.3.1 Results and discussion of the effect of age/feeding regime on cooking loss, thawing loss and shear force (WBSF) of loin, rib-eye and rump

The mean values of the effect of age and feeding regime on cooking loss, thawing loss and shear force are tabulated in Table 4.5. The loin cut will be discussed first followed by the rib-eye and the rump.

TABLE 4.5: MEAN VALUES AND STANDARD ERROR OF MEANS FOR THE EFFECT OF AGE/FEEDING REGIME ON THE WARNER BRATZLER SHEAR FORCE (WBSF), COOKING AND THAWING LOSSES OF THE LOIN, RIB-EYE AND RUMP

CUT		AGE GROUP							
LOIN	**ATTRIBUTE**	**AG**	**ABG**	**AF**	**ABF**	**B4**	**B6**	**SEM**	***P* value**
%	Cooking loss	22.5^{bc}	21.7^{ab}	24.0^{c}	20.4^{a}	20.0^{a}	20.2^{a}	0.707	0.001
%	Thawing loss	2.85	2.99	2.65	3.52	2.95	2.72	0.210	0.072
KG	WBSF	3.33	3.51	3.22	3.77	3.64	3.85	0.196	0.187
RIB-EYE									
%	Cooking loss	23.1	21.7	23.0	21.1	21.7	21.4	0.597	0.104
%	Thawing loss	2.27	2.18	1.94	2.82	2.47	2.37	0.201	0.072
KG	WBSF	3.58	3.77	3.26	4.16	3.80	3.81	0.212	0.100
RUMP									
%	Cooking loss	22.1	21.4	23.3	21.9	22.4	20.9	0.537	0.060
%	Thawing loss	3.60^{ab}	3.50^{ab}	3.41^{a}	4.40^{b}	4.44^{b}	4.09^{b}	0.227	0.003
KG	WBSF	3.17	3.45	3.43	3.70	3.89	3.73	0.186	0.107

***a,b,c* Means in the same row with different superscripts differ significantly (P<0.05)**
SEM Standard error of mean

4.3.1.1 Cooking loss

Cooking loss was affected by age in the loin cut with older animals recording lower amounts of cooking loss compared to AF which had the highest amount of cooking loss followed by the two grain fed groups, AG and ABG. This result is in contrast to that of Schönfeldt and Strydom (2011a) who found that cooking losses increased with increasing animal age due to decreased water holding capacity and increased moisture loss brought by denaturation of protein or increased cross linking of collagen with age. Cooking loss consists of stock (meat juices) and fat drip. The higher cooking losses for the grain fed groups in the present study correspond with higher carcass fat codes and probably more fat in the cuts. In the rib-eye and rump cuts, age had no significant effect on cooking loss, although AF still recorded the highest scores in both of these cuts.

4.3.1.2 Thawing loss

Thawing loss was not affected by age class or feeding regime in the loin and rib-eye. It must be noted that in both of these cuts thawing loss was greater in the older animals than in the younger animals. In the rump cut thawing loss differed significantly, with the older free-range animals having the highest amount of thaw loss. Thawing losses were higher for rump steaks of ABF, B4 and B6 compared with AF, ABG and AG. This difference in thawing loss between the younger and older animals can be attributed to decreased water holding capacity and increased moisture loss brought by denaturation of protein or increased cross linking of collagen with age (Schönfeldt & Strydom, 2011a).

4.3.1.3 Warner Bratzler shear force

Warner Bratzler shear force was not affected by age/feeding regime in any of the cuts.

4.3.2 Results and discussion of the effect of post-mortem aging on cooking loss, thawing loss and shear force (WBSF)

Mean values and the effect of post-mortem aging on Warner Bratzler shear force, cooking and thawing losses of loin, rib-eye and rump are presented in Table 4.6.

TABLE 4.6: MEAN VALUES AND STANDARD ERROR OF MEANS FOR THE EFFECT OF POST-MORTEM AGING ON WARNER BRATZLER SHEAR FORCE (WBSF), COOKING AND THAWING LOSSES OF LOIN, RIB-EYE AND RUMP

CUT		**AGING PERIOD**			
LOIN	**ATTRIBUTE**	**36 days**	**55 days**	**SEM**	***P* value**
%	Cooking loss	21.2	21.7	0.270	0.226
%	Thawing loss	3.09	2.80	0.097	0.041
KG	WBSF	3.64	3.46	0.086	0.150
RIB-EYE					
%	Cooking loss	21.9	22.1	0.223	0.660
%	Thawing loss	2.50	2.18	0.105	0.036
KG	WBSF	3.76	3.70	0.080	0.571
RUMP					
%	Cooking loss	21.9	22.1	0.278	0.584
%	Thawing loss	3.96	3.85	0.109	0.450
KG	WBSF	3.70	3.42	0.084	0.023

***a, b, c, d* Means for attributes with P values < 0.05 were considered significantly different**

SEM Standard error of mean

The results indicate that neither cooking loss nor shear force (WBSF) was affected by post-mortem aging in both the loin and rib-eye cuts. According to Jeremiah and Gibson (2003), no relationship was found between aging time, thawing loss and cooking loss. However, thawing loss in both of these cuts was affected by post-mortem aging period; the 36 day aged samples had more thawing loss that the 55 days aged samples. This difference can be attributed to the increase in water holding capacity of meat during post-mortem aging (Kołczak, Krzysztoforski & Palka 2007). This increment in water holding capacity is as a result of the degradation of myofibrillar and cytoskeletal proteins during post-mortem aging which result in a looser muscle structure (Huff-Lonergan & Lonergan, 2005).

In the rump cut cooking loss and thawing loss were not affected by aging however, WBSF values were higher at 36 days compared to 55 days. No relationship was found between aging time, thawing loss and cooking loss (Jeremiah & Gibson, 2003).

Sensory tenderness scores were compared to the instrumental tenderness scores. The mean sensory scores for loin cuts of the AG, ABG and AF groups recorded mean values around 5.5 describing them as slightly to fairly tender. Warner Bratzler shear values were in the region of 3.4kg. Corresponding mean sensory values for tenderness of the ABF and B4 and B6 groups were around 4.5, meaning they were slightly tender, while Warner Bratzler shear force values were in the region of 3.75kg.

Warner Bratzler thresholds values have been determined in different studies to give an indication of the different categories of tenderness and how the consumers relate to these categories. Destefanis *et al.* (2007) reported that steaks with Warner Bratzler shear force values greater than 5.2kg are classified as tough and those less than 4.2kg are regarded as tender. Shackelford, Morgan, Cross and Savell (1991) reported threshold values of 4.6kg and 3.9kg for “retail” (shops) and “food service” beef (restaurants). Therefore one needs at least a shear force of 4.6kg to have a steak rated at least “slightly tender” by consumers purchasing from retail outlets.

According to Boleman, Boleman, Miller, Taylor, Cross, Wheeler, Koohmaraie, Shackelford, Miller, West, Johnson and Savell (1997) consumers were able to differentiate between three categories of tenderness based on Warner Bratzler shear force, namely; 2.3 to 3.6kg, 4.1 to 5.4kg and 5.9 to 7.2kg. In their study, 94% of the consumers were satisfied with the first category (2.3-3.6 kg) and was willing to pay a premium for improved tenderness. Using these categories, it seems that the two grain fed groups AG and AF fall within the range of that is perceived to be the most tender and may be most ‘acceptable’ to the consumer. The older free-range groups were wedged between the best and second best category meaning that they may have a slight risk of not satisfying the consumers always.

4.4 PRINCIPAL COMPONENT ANALYIS OF THE EFFECT OF AGE/FEEDING REGIME AND POST-MORTEM AGING ON JUICINESS, TENDERNESS RELATED ATTRIBUTES AND FLAVOUR UNDERETONES OF THE LOIN, RIB-EYE AND RUMP

Multivariate statistics (Principal Component Analyses, PCA) was used to summarise our results on sensory analyses for the three cuts of different age/feeding regime/aging groups, this was done in order to determine which sensory attributes separate the different groups from each other. PCA considers all twelve sensory attributes to show the relationship (grouping) among the six age/feeding regime groups and two post-mortem aging treatments. The results are then presented in a two dimensional chart (biplot) where the positions of the treatment groups demonstrate their relationship to each other considering the contribution of each sensory attribute.

The chart is therefore interpreted in two dimensions, vertical and horizontal, by the distances from the centre point. On each level a certain percentage of the variation among groups is explained. The direction (left, right, up or down) and the distance relative to the centre point of sensory attributes and treatment groups explain the relationship of the treatment groups to each other and the relationship of the attributes to the treatment groups.

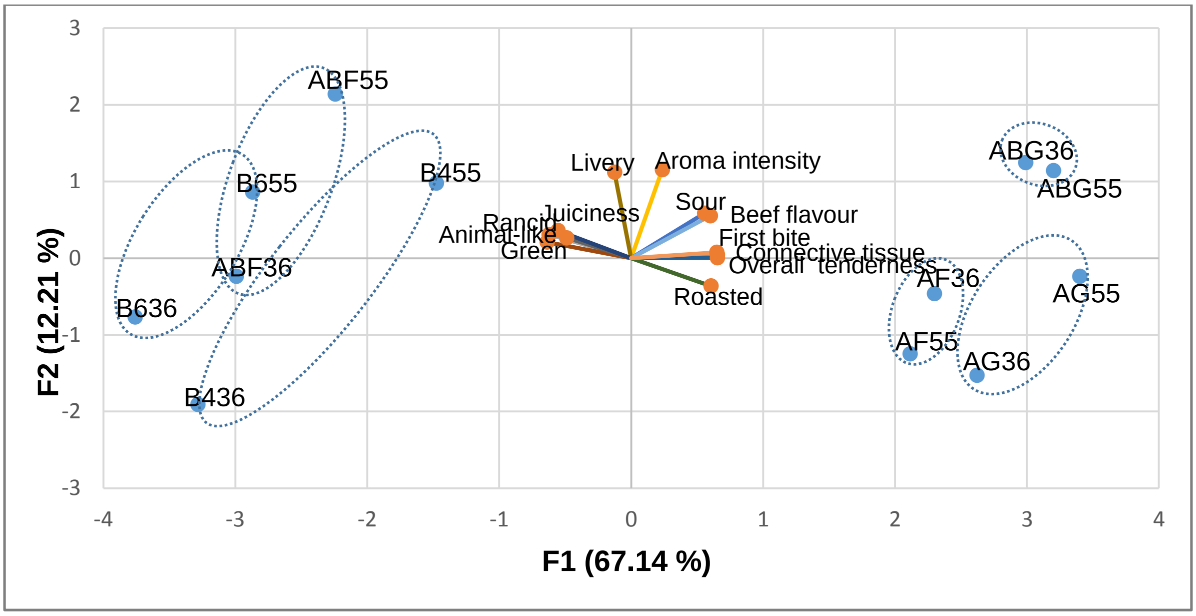


FIGURE 4.7: PRINCIPAL COMPONENT BI-PLOT SHOWING SCORES (TREATMENT GROUPS) AND LOADINGS (ATTRIBUTES) FOR THE TWO FIRST COMPONENTS F1 AND F2: (EXPLAINING 79.34% OF VARIATION AMONG TREATMENT GROUPS): LOIN

Figure 4.7 shows the positioning of the different treatment groups of the loin cut. All AG, AF and ABG (36 and 55) groups lie on the right hand side of the graph while the ABF, B4 and B6 (36 and 55) lie on the opposite end of the graph. This means that the younger free-range group and both grain fed groups separate from the older free-range groups. The sensory attributes first bite, overall tenderness, connective tissue , beef flavour sour, roasted flavour are placed farthest from the centre to the right on the horizontal axis. This is in contrast to the attributes livery, juiciness, rancid, animal-like and green which lie farthest from the centre to the left.

The horizontal level explains 67.14% variation and show that the three younger groups separate from the older groups because of the higher scores for sensory attributes first bite, overall tenderness, connective tissue , beef flavour, sour, roasted flavour. The younger groups will in turn have lower scores of rancid, animal-like and green undertones. B436 lies farthest away from the centre compared to B455 which means that the attributes, juiciness, rancid, animal-like and green were more pronounced in B455 than they were in B436.

Livery flavour and aroma did not contribute to the separation of the groups on the horizontal level, although both of these attributes had a strong positive direction and distance in the vertical dimension. As a result we would expect B436 and AG36 to have lower scores of these attributes and ABF 55 to have higher scores, although this level explains only 12.21% of the variation.

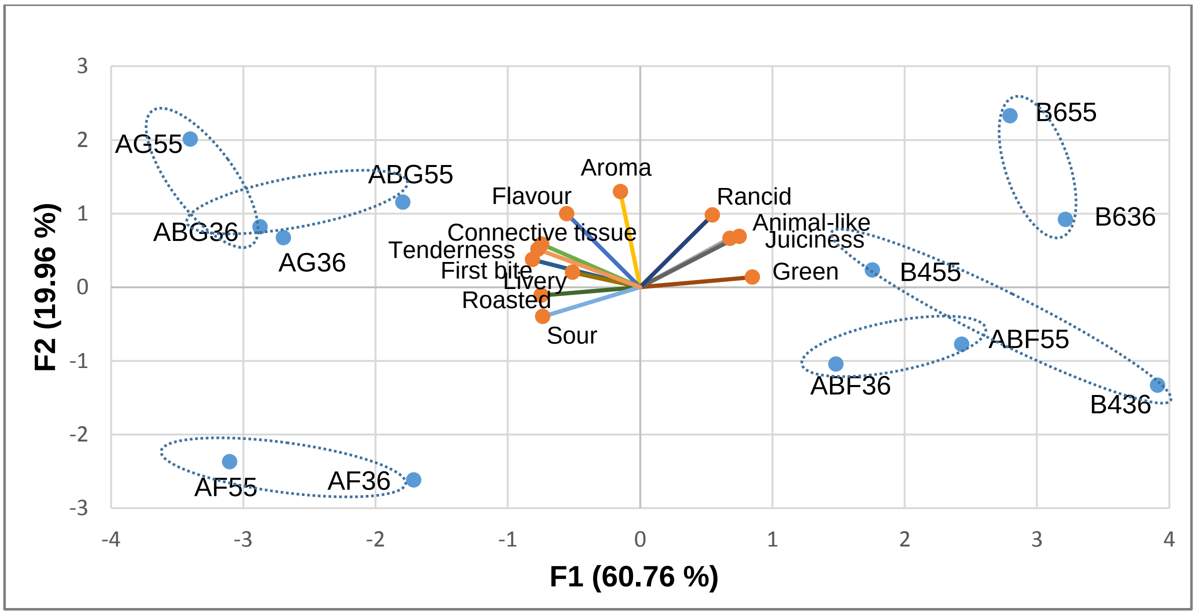


FIGURE 4.8: PRINCIPAL COMPONENT ANALYSES: BI-PLOT SHOWING SCORES (TREATMENT GROUPS) AND LOADINGS (ATTRIBUTES) FOR THE TWO FIRST COMPONENTS F1 AND F2: (EXPLAINING 80.72% OF VARIATION AMONG TREATMENT GROUPS): RIB-EYE

In Figure 4.8 the positioning of the different treatment groups is shown for the rib-eye cut. The same separation as experienced in the loin was seen but the directions of the attributes and treatment groups were swapped around. The horizontal level explained 60.76% variation among groups while the vertical level explained 19.96% variation. The attributes green, juiciness, animal-like and rancid were associated with older free-range animals whereas the younger animals were associated with sensory attributes of sour, roasted, tenderness, livery , first bite, connective tissue and beef flavour. On the vertical level aroma, beef flavour and rancid flavours played a significant role as a result it is expected that AF36 and AF55 will have lower scores of these attributes compared to B655 and AG55 which are expected to have higher scores.

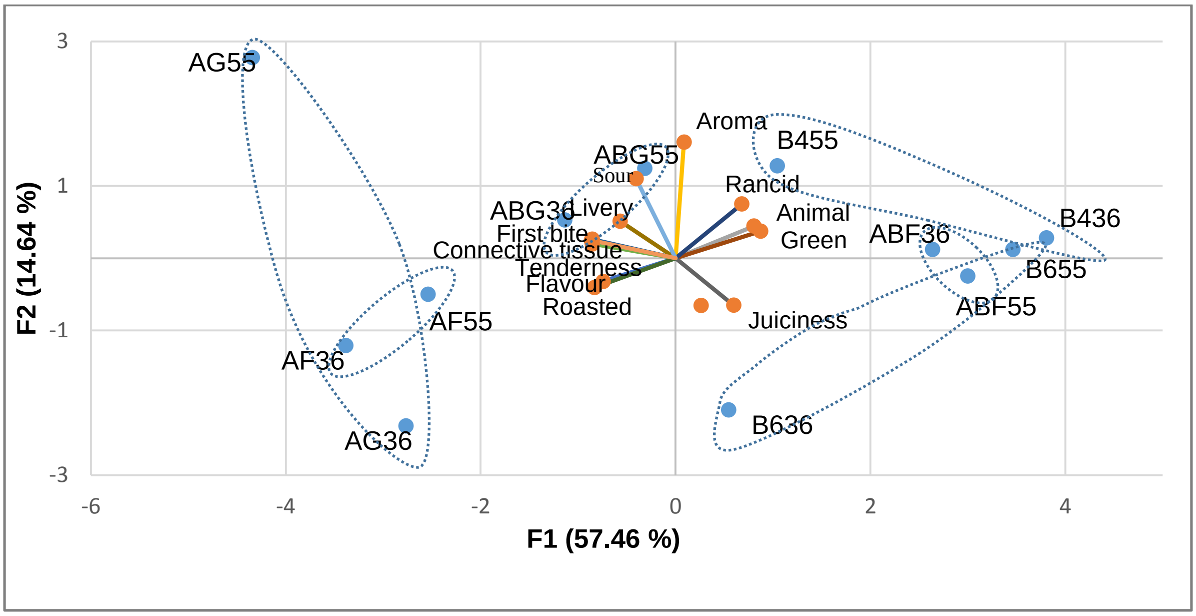


FIGURE 4.9: PRINCIPAL COMPONENT ANALYSES: BI-PLOT SHOWING SCORES (TREATMENT GROUPS) AND LOADINGS (ATTRIBUTES) FOR THE TWO FIRST COMPONENTS F1 AND F_2: (EXPLAINING 72.1% OF VARIATION AMONG TREATMENT GROUPS): RUMP CUT

According to Figure 4.9, the rump also followed the same pattern as the previous cuts, with a separation between the younger animals and the older free-range animals However in contrast to the other cuts the older grain fed group ABG (36 and 55) was closer to the centre on the horizontal level meaning that it was not clearly differentiated from the other groups by the different variables. The same applied to the B455 and B636. The horizontal level explained 57.46%. The attributes tenderness, connective tissue, first bite, roasted, beef flavour, livery were related to the younger animal groups whereas rancid, animal green and juiciness were related to older free-range animals. On the vertical level, which explains 14.64% variation, aroma and sour had a strong positive displacement meaning AF36 and AG 36 will have lower scores of these attributes in contrast to AG55 which will have higher scores of these attributes.

4.5 SPIDER PLOTS OF THE LOIN, RIB-EYE AND RUMP CUTS OF DIFFERENT AGE/FEEDING REGIME AND AGING GROUPS

Figure 4.10 displays spider plots of the three selected beef cuts as they are affected by age/ feeding regime.

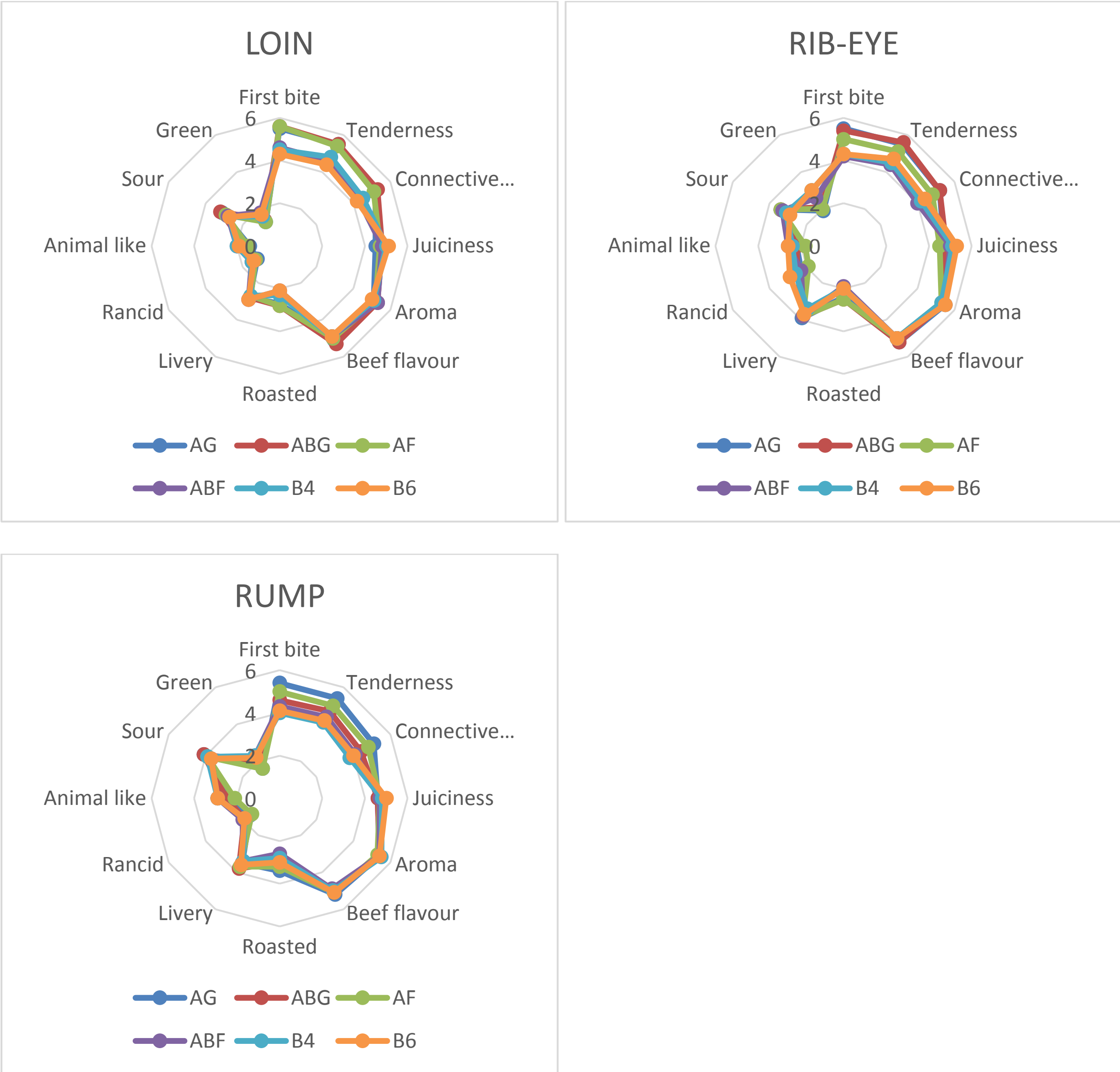


FIGURE 4.10: SENSORY PROFILES OF THE LOIN, RIB-EYE AND RUMP CUTS FOR SIX AGE/FEEDING REGIME GROUPS

Spider plots are presented as comparisons of each attribute of all the products tested. These graphs were plotted using the mean values as generated by ANOVA. The twelve attributes plotted are: animal, aroma, beef flavour, connective tissue, first bite, green, juicy, liver, rancid, roasted, sour and tender. All twelve attributes of the three beef cuts (loin, rib-eye and rump) as affected by age and feeding regime are plotted on three separate graphs. From Figure 4.10 one can see that although the plots of the different treatments look alike there are many differences in terms of the scores (intensities) of the attributes. For all the cuts the attributes; tender, first bite, roasted and beef flavour have higher scores in the younger and grain fed animals (AG, AF, ABG) than in the older free-range groups (ABF, B4 and B6). The attributes sour, livery, green rancid and juicy were more pronounced in the older free-range groups but at very low intensities except for juicy which had high scores.

FIGURE 4.11: SENSORY PROFILES OF THE LOIN, RIB-EYE AND RUMP CUTS OF TWO POST-MORTEM AGING GROUPS

No differences are observed in the plots of the two different post-mortem aging groups. This fact has already been explained in section 4.6.3.

4.6 CONCLUDING SUMMARY

In this chapter the results were presented and discussed. The presentation of these results was done in two phases according to how the study was undertaken. In the first phase of the study sensory analysis was performed and these results were analysed statistically using ANOVA to determine significant differences. The second phase employed objective evaluation where the Warner Bratzler shear force device was used to measure tenderness, added to this both thawing and cooking losses were also determined. The results obtained were also analysed statistically using ANOVA to determine significant differences. The results were further analysed by means of PCA a multivariate technique, to determine which attributes contributed to the difference between the different groups. The chapter that follows will conclude the study, highlight the limitations encountered and propose recommendations for future studies on this subject.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the main findings, conclusions and implications of the findings. It further provides a reflection on the research and discussion of the limitations encountered. At the end of this chapter recommendations for future studies are also proposed. The aim of this study was to determine and describe the eating quality of selected beef cuts produced from Namibia. These beef cuts originate from cattle of different age classes, feeding regimes and post-mortem aging periods. The developed sensory profiles will be used by MEATCO to improve their product lines in order to satisfy the needs of the different consumers that they have. The samples for this study were acquired from MEATCO Namibia, but the study itself was conducted at the sensory laboratory of Agricultural Research Council in Irene during the year 2013.

In this quantitative study, data was collected in three ways: by means of a cooking form (recording thawing and cooking losses) sensory evaluation (intensity of the different attributes measured by the taste panel) and the Warner Bratzler shear force device mounted on a Universal Instron machine (Instron 4500, series IX version 5, Massachusetts) was used to record shear force data. Least Significant Difference (LSD) test, Analysis of Variance (ANOVA) and Principal Component Analysis (PCA) were the three statistical techniques used to determine whether significant differences existed between the beef samples.

The experimental design and conceptual framework developed contributed to achieving the main aim of the study. The factors as presented in this framework have an influence on the eating quality of the loin, rump and rib-eye cuts, namely; age class, feeding regimes and aging periods were presented. These factors affect eating quality of meat at different production stages such as primary production, pre and post-slaughter handling and during the cooking process. Under primary production, two variables that were studied are age classes and feeding regime, whereas under post-slaughter handling the variable studied was aging period. It was found that each of these variables had an effect (either positive or negative) on at least one of the eating quality attributes of meat that were evaluated.

5.2 RESEARCH IN RETROSPECT

5.2.1 Introduction and planning

This study followed a deductive approach, meaning that a thorough investigation of existing literature pertaining to eating quality and sensory profiling was conducted to guide the development of the problem statement and objectives. Relevant and recent literature on the subject of eating quality of beef was limited and mainly from the United States, Australia and European countries and could not always be applied to the Namibian context.

Before commencement of the data collection, approval from the Ethics committee of the Faculty of Natural and Agricultural Sciences had to be granted. Following this approval, a pilot study was conducted to standardise the data collection procedure. It was also during the pilot study that the cooking procedures and sensory evaluation methods were developed.

After the pilot study was completed, the training of the sensory evaluation panel commenced. This is where the sensory attributes of meat that were to be evaluated in the study were introduced to the panel. A lexicon was also developed by the panel leader with the aid of the panel members to give a thorough description of each of the sensory attributes evaluated in order to minimise ambiguity and ensure that each attribute is evaluated correctly. Data collection commenced in March 2013 and was concluded in September of the same year.

5.3 MAIN FINDINGS

Age class of the animal had a negative effect on tenderness as well as typical beef flavour because the scores for these attributes decreased with increasing age. In contrast age class had a positive effect on juiciness as this attribute increased with increasing animal age. The feeding regime that the animals were subjected to pre-slaughter also had an effect on the sensory attributes evaluated. Feeding regime had the most effect on aroma and flavour and to a lesser extent on tenderness and juiciness. Post-mortem aging had very little effect on the sensory attributes evaluated in this study. With the exception of the sensory attribute connective tissue residue of the loin, beef flavour of the rib-eye and animal-like flavour of the rump, there were no significant differences found between the 36 and 55 days aged samples.

5.4 CONCLUSIONS

5.4.1 Conclusions on the sensory attributes of three selected cuts of various age classes, feeding regime and post-mortem aging periods: Objective 1

The first objective of the study was to determine, describe and compare the sensory attributes namely, aroma, tenderness, juiciness and flavour of the three selected cuts of import beef (loin, rib-eye and rump).

Twelve attributes (aroma, first bite, tenderness, connective tissue, juiciness, typical beef flavour, roasted beef, beef meat, rancid, animal-like, sour and green flavours) were identified to describe the eating quality of each of the selected import cuts. For each cut, the responses of the panellists to the effect of each of the variables were different for the three cuts. The three variables studied (age classes, feeding regime and post-mortem aging), all had an effect on the overall eating quality of each cut, but the extent of the effect of each variable differed.

The effect of age and feeding regime was analysed using ANOVA and it determined that for all three cuts (loin, rib-eye and rump) a significant difference was found in at least ten (first bite, tenderness, connective tissue, juiciness, beef flavour, roasted, rancid, animal-like, sour and green flavours) of the twelve attributes. The effect of post-mortem aging on eating quality was also studied. ANOVA determined that for all three cuts (loin, rib-eye and rump) only two (connective tissue and beef flavour) of the twelve attributes showed a significant difference. This indicates that the eating quality of the beef cuts differed mainly due to the differences in age classes and feeding regime and very small differences were observed due to post-mortem aging.

Comparison of the age classes of the different cuts shows that the differences were brought about by juiciness and tenderness related attributes because younger animals tended to be more tender than their older counterparts and the latter were juicier than their younger counterparts. The difference in eating quality was also affected by typical beef flavour and flavour undertones. Typical beef flavour and roasted flavours decreased with increasing age class, whereas 'negative' flavour undertones like beef meat, rancid, animal-like, sour and green were perceived more in older free-range animals than in younger animals.

Tenderness and flavour are the two most important eating quality attributes sought after by consumers. It is thus important for MEATCO to ensure consistency of these attributes in beef that they trade with. From this study it is suggested that even though extreme post-mortem aging resulted in acceptable tenderness levels for all age classes and feeding regimes, the consumer may still pick up flavour differences between the different age and feeding regimes groups.

A single product line including all age classes will therefore result in an inconsistent eating experience for the consumer and increase the risk of consumer complaints. It is therefore recommended that to satisfy the majority of the South African consumers, this beef meat must be marketed as two separate product lines. The younger free range (AG) and the two grain fed groups (AG and ABG) can be marketed as one product line and the ABF, B4 and B6 groups marketed as another product line. South African consumers are unfamiliar with the flavours of older free-range meat because most of the meat consumed in South Africa is from younger grain fed animals.

5.4.2 Conclusions on the physical attributes of three selected cuts of various age classes, feeding regime and post-mortem aging periods: Objective 2

The second objective of the study was to determine, describe and compare physical attributes of the three selected beef cuts produced in Namibia. The physical evaluation included shear force resistance measurement, thawing and cooking losses calculations. The loin, rib-eye and rump cuts were used to measure the physical attributes mentioned.

ANOVA determined that in all three cuts at least one of the three attributes (cooking loss, thawing loss and instrumental tenderness) was significantly different. This shows that age class, feeding regime and prolonged post-mortem aging had very little effect on the physical properties (shear force, cooking and thawing losses) of the selected beef cuts. Although objective evaluation is said to be a more reliable form of measurement when compared with sensory evaluation, the results obtained in this study from physical measurement proved otherwise. It can be concluded that Warner Bratzler shear force measurements have low predictive value with respect to consumer evaluations of tenderness, and by implication also with respect to consumer satisfaction and likelihood of repeat purchases.

5.4.3 Conclusions with regard to the compilation of the sensory profiles of the sensory attributes: Objective 3

The third objective of the study was to compile a profile of the sensory attributes of aroma, juiciness, tenderness and flavour for each cut of beef, for the different age classes, feeding regimes and post-mortem aging periods. The twelve attributes that were identified and evaluated by the sensory panel were used to plot sensory profiles (spider plots) of each of the selected import beef cuts. These were presented in Figures 4.10 and 4.11 in the previous chapter.

Spider plots have the ability to communicate efficiently and effectively, by expressing information clearly and accurately to the viewer. The information contained in tables is often difficult for the reader to follow but a graphical representation of the data makes it easier to interpret data. The advantage of spider plots is that all the sensory attribute data is summarised. The effects of all variables (age classes, feeding regime and post-mortem aging) on the different eating quality attributes (aroma, juiciness, tenderness and flavour) can be seen at one glance.

5.5 LIMITATIONS OF THE STUDY

In conducting a study there are often limitations present. This study was no exception and the main limitation of this study was related to other sensory and physical measurements that were not performed during the execution of this study.

5.5.1 Consumer sensory evaluation

Descriptive analyses are very useful in situations where detailed specification of sensory attributes of a single product is desired (Gillette, 1984 as cited in Lawless and Heymann, 1998:341). These methods tend to be very expensive for day to day quality control situations but are very helpful when troubleshooting major customer complaints as is the case with the present study (Lawless and Heymann, 1998: 342). However the results of descriptive evaluation only provide information about the sensory properties of the product and no information on consumer preferences, (Curtis, 2013: 215). Due to limited funds, lack of sufficient sample numbers and MEATCO requiring the results in a short space of time a consumer sensory panel could not be conducted. This information would have been of great importance as it would have given an indication of the consumers' hedonic response.

5.5.2 Other physical measurements

In this study, shear force of the cooked meat samples was measured and cooking and thawing losses were calculated. Colour of the meat and fat content form part of the physical evaluation for the physical evaluation of raw meat samples but these were not performed/determined. Colour measurements and the determination of fat content added to other objective evaluations performed, would have provided and enhanced representation of the physical properties of the selected beef cuts.

5.6 RECOMMENDATIONS FOR FUTURE RESEARCH

Meat cuts exported to South Africa by Meatco are mostly high quality cuts targeted for restaurant or barbeque purposes, such as the rump, sirloin and rib-eye. The meat is highly valued in terms of eating quality and safety as it is also exported to the European Union which has high hygiene and safety standards that need to be adhered to. The data that is now available on the eating quality of the particular cuts will serve as guideline to MEATCO for consideration in further development of product lines. The following are recommendations for future studies:

The problem statement for this study originated from the consumer complaints about the inconsistent eating quality of MEATCO beef. It is recommended that in future studies, sensory evaluation by a consumer panel be included. The results of consumer panels can help researchers to evaluate the intent of their target market as these tests are preferred for product testing (Cox, 2013: 233).

Meat is consumed after having undergone some kind of preparation. The result of preparation (cooking) of the product at home and not only the inherent product attributes determines customer satisfaction (Grunert, 2002). Cooking skill is not a simple construct and is usually measured through self-evaluation (Grunert, 2002). Ideally meat prepared by grilling or barbecue should be cooked to an internal temperature of 70°C. If meat is cooked to internal temperature between 74-80°C, it tends to dry out and become tough. This will affect consumers' perception of meat and result in dissatisfaction. However, consumer satisfaction can be optimised by educating the consumer on principles of meat cookery.

Home-use tests could give more realistic results for product testing because these tests allow the panellists to evaluate the product under normal circumstances on numerous occasions in their homes (Curtis, 2013:216). The researcher can be present during the cooking process and evaluate the meat after it has been cooked by the consumer. This will give the researcher insight into the role that cooking skills play in consumer satisfaction.

5.7 IMPLICATIONS OF THE FINDINGS

The findings of this study provided empirical evidence that can be useful to the producers of beef meat. Distinct differences in eating quality of meat were evident: meat from younger animals (A- class) was more tender and had more beef flavour identity, whereas meat from older animals (AB and B classes), although more juicy, was perceived as slightly tougher and also had flavours that would not be desirable to most South African consumers.

A variance in tenderness and flavour of meat is not something that can be overlooked as these two attributes are highly sought after by consumers. The spider plots in chapter four (see Figures 4.10 and 4.11) clearly illustrated that the younger free- range group AF and the two grain fed groups ABG and AG show similarities in most of their sensory attributes especially in the loin and rib-eye cuts. These age/feeding regime groups can be marketed under the same product line. Meat producers should however be very cautious about the ABG group which tends to differ slightly from the much younger groups, AF and AG.

The groups ABF, B4 and B6 also have similar profiles. These age/ feeding regime groups can be marketed as a single product line that is different from the younger groups. The South African consumer is accustomed to meat from younger animals so the AF, AG and ABG product line is bound to satisfy majority of these consumers even those that like free- range meat may find the flavour of AF acceptable than they would the flavours of ABF, B4 and B6, which may be perceived as 'off flavours'. The European consumer on the other hand might be satisfied with the product line that includes the groups ABF, B4 and B6. These consumers are accustomed to flavours of older free- range meat, since they require meat from carcasses originating from B2, B3 and B4. The sensory profiles of the 36 and 55 days aged samples did not show any differences, thus after 36 days of post-mortem aging the meat will have reached the maximum tenderness level. Aging the meat beyond 36 days but probably not exceeding 55 days will not affect the eating quality of the meat negatively.

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ADDENDUM A

PROOF OF APPROVAL FOR THE STUDY FROM THE ETHICS COMMITTEE

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

ETHICS COMMITTEE

Faculty of Natural and Agricultural Sciences

17 February 2014

Dr AT Viljoen

Department of Consumer Sciences

University of Pretoria

Pretoria

0002

Dear Dr Viljoen

EC140114-002: Sensory profiles and the effect of age, feeding regime and aging on quality of selected beef cuts

Your application conforms to the requirements of the NAS Ethics Committee

Kind regards

Prof NH Casey

Chairman: Ethics Committee

ADDENDUM B

COOKING DATA SHEET USED IN THE STUDY

DRY HEAT COOKING METHOD **DATE:**

SE CODE:	
PROJECT: **Sample code**: …………… …………..	
THAWING DATA	
Mass raw sample + thawing loss + bag	……………..g
Mass bag + exudate	……………..g
Mass bag without exudate	……………..g
COOKING DATA	
Time in: ………………… **Cooking time (h):** ……………………	
Time out: ……………….	
Oven number: …………… **Start temp:** ………..ºC **End temp:** ………..ºC	
	Mass (g)
Mass of pan + rack	……………..g
Mass pan + rack and raw meat	……………..g
Mass pan + rack + drip loss + **cooked meat**	……………..g
Mass pan rack + drip loss	……………..g
Mass pan + rack + residue drip	
Mass residual drip loss in pan (calculated (g))	……………..g
CYLINDER READING	
Total drip loss	……………..g
Stock	……………..g
Fat Total volume of fat (calculated (ml)) Mass of fat (calculated (g))	……………….g

ADDENDUM C

EVALUATION FORM AND LEXICON USED IN THE STUDY

TABLE C1: THE SENSORY EVALUATION FORM USED BY THE PANNELLISTS TO EVALUATE THE MEAT FOR THE STUDY

SENSORY EVALUATION OF BEEF **Session** **DATE:**

Name:……………………………. ……….. **Panellist no:…………………….**

Please evaluate the following samples of BEEF for the designated characteristics.

Characteristics	Rating scale	Sample codes			
		720	770	820	870
AROMA INTENSITY Take a few short sniffs as soon as you remove the foil Bland = No flavour or taste factors perceptible	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				
Comments on aroma	Please describe the aroma				
FIRST BITE The impression that you form on the first bite	1 = Extremely tough 2 = Very tough 3 = Fairly tough 4 = Slightly tough 5 = Slightly tender 6 = Fairly tender 7 = Very tender 8 = Extremely tender				
IMPRESSION OF JUICINESS The impression of juiciness that you form as you start chewing	1 = Extremely dry 2 = Very dry 3 = Fairly dry 4 = Slightly dry 5 = Slightly juicy 6 = Fairly juicy 7 = Very juicy 8 = Extremely juicy				
MUSCLE FIBRE & OVERALL TENDERNESS Chew sample with a light chewing action	1 = Extremely tough 2 = Very tough 3 = Fairly tough 4 = Slightly tough 5 = Slightly tender 6 = Fairly tender 7 = Very tender 8 = Extremely tender				
AMOUNT OF CONNECTIVE TISSUE (RESIDUE) The chewiness of the meat	1 = Extremely abundant 2 = Very abundant 3 = Excessive amount 4 = Moderate 5 = Slight 6 = Traces 7 = Practically none 8 = None				
OVERALL <u>BEEF FLAVOUR</u> INTENSITY This is the combination of taste while chewing and swallowing	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				

This is the combination of taste while chewing and swallowing

Characteristics	Rating scale	Sample codes			
		720	570	620	670
ROASTED BEEF • Caramel/Caramelized • Fat, browned	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				
BEEF-MEAT • Metallic (tin/aluminum) • Livery (metallic/bloody) • Bloody	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				
RANCID MEAT • Rancidity • Soapy • Fatty	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				
ANIMAL-LIKE Barnyard/Animal Musty/Earthy Spoiled /Putrid	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				
SOUR MEAT Sour	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				
GREEN Grassy/ shrub “Bossie”	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				
WARMED-OVER FLAVOUR Warmed-over	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				

TABLE C2: LEXICON USED BY THE PANELLISTS TO EVALUATE THE MEAT FOR THE STUDY

Attribute	Description / Definition
Roasted beef	
Caramel / Caramelized	Characteristic of browned sugar and some other carbohydrates.
Fat, browned	Aromatics reminiscent of drippings of meat and fat in a pan after meat has been broiled. Also flavour of meat browned in skillet and associated fried fat (drippings)
Beef-meat	
Metallic (tin/aluminum)	A flavour associated with the inside of an empty can, tinny. Impression of slightly oxidized metal, such as iron. Copper and silver spoons. Regarded as a negative attribute.
Livery (metallic/bloody)	Aromatics associated with cooked organ meat/liver.
Bloody	Aromatic taste sensation associated with raw (rare) lean meat, cooked blood, serum.
Rancidity	
Rancid	A bitter taste due to oxidised fats or oils e.g. including cardboard, painty, vanish and fish as well as aged potato chips, old oxidised oil.
Soapy (Chemical)	General term for aromatics associated with many different types of compounds, such as solvents, cleaning compounds, unscented hand sop and hydrocarbons.
Fatty	Fat-like, associated with cooked animal fat.
Animal-like	
Barnyard/Animal	Aromatic characteristics of barn or barnyard; combination of manure, urine, moldy hay, feed, livestock odors
Musty/Earthy	Aroma associated with closed air spaces such as attics, closets (dry) and basements and turned soil (wet).
Spoiled /Putrid	Aromatic associated with anaerobic protein decomposition, decaying vegetation or animal.
Sour meat	
Sour	Aromatics reminiscent of fruit.
Green	
Grassy/ shrub	Green, slightly sweet aromatic associated with cut grass, parsley, pea, spinach, fresh cut grass. In meat flavor associated with beef fed a diet of primary grasses.
Warmed-over flavour	
Warmed-over	Aromatics of uncured cooked meat after 4 - 48 hours of refrigerator storage and reheating. Perceived as stale, cardboard, or rancid.

ADDENDUM D

TABLE D1: SAMPLING OF THE DIFFERENT CUTS OF MEAT

Post-mortem aging	36 days						55 Days					
Feed	Grain fed	Free-range	Grain fed	Free-range	Free-range	Free-range	Grain fed	Free-range	Grain fed	Free-range	Free-range	Free-range
Age classes	AG	AF	ABG	ABF	B4	B6	AG	AF	ABG	ABF	B4	B6
No. of sample per cut	10	10	10	10	10	10	10	10	10	10	10	10

A= **0 permanent incisors**

AB= **2 permanent incisors**

B4= **4 permanent incisors**

B6= **6 permanent incisors**

G = **Grain fed (feedlot)**

F = **Free-range (grass-fed)**

ADDENDUM E

PHOTOGRAPHS

FIGURE 1: FROZEN CUTS OF MEAT REMOVED FROM BAGS IN PREPARATION FOR PROCESSING INTO STEAKS

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FIGURE 2: FROZEN STEAKS PACKED INTO BAGS AND VACUUM SEALED.

FIGURE 3: STEAKS WERE THAWED OVERNIGHT PRIOR TO COOKING.

FIGURE 4: MEAT IS WEIGHED PRIOR TO COOKING

FIGURE 5: THAWING LOSSES ARE CALCULATED

FIGURE 6: MEAT IS GRILLED IN A 200^{O}C OVEN AND TURNED HALFWAY THROUGH THE COOKING PROCESS

FIGURE 7: THE MEAT IS COOKED TO INTERNAL TEMPERATURE OF 70^{O}C AND WEIGHED POST COOKING TO CALCULATE LOSSES.

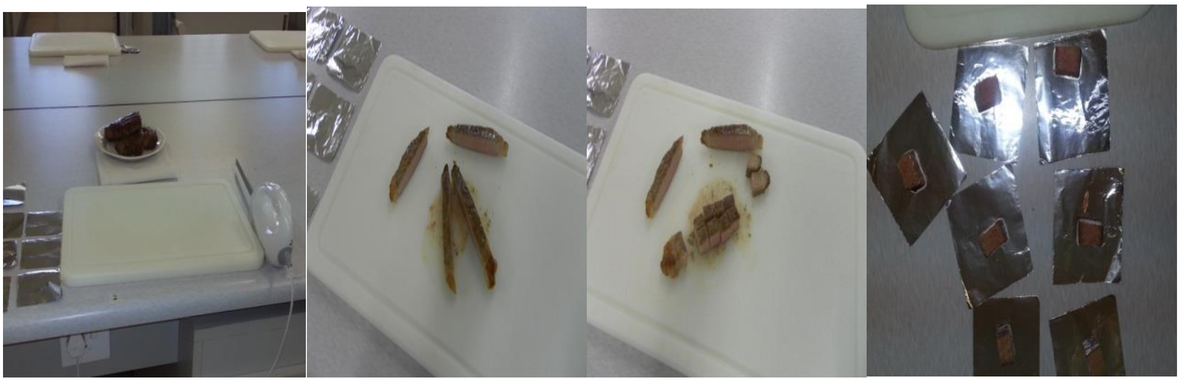

FIGURE 8: MEAT IS CUT LENGTHWISE AND THEN CUT INTO SQUARES AND WRAPPED IN FOIL

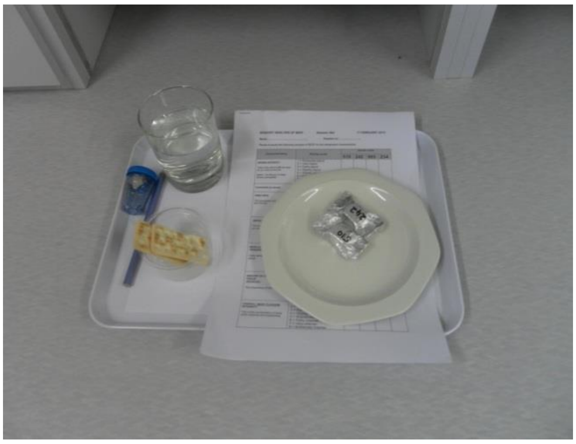

FIGURE 9: PRESETANTION TO THE PANEL

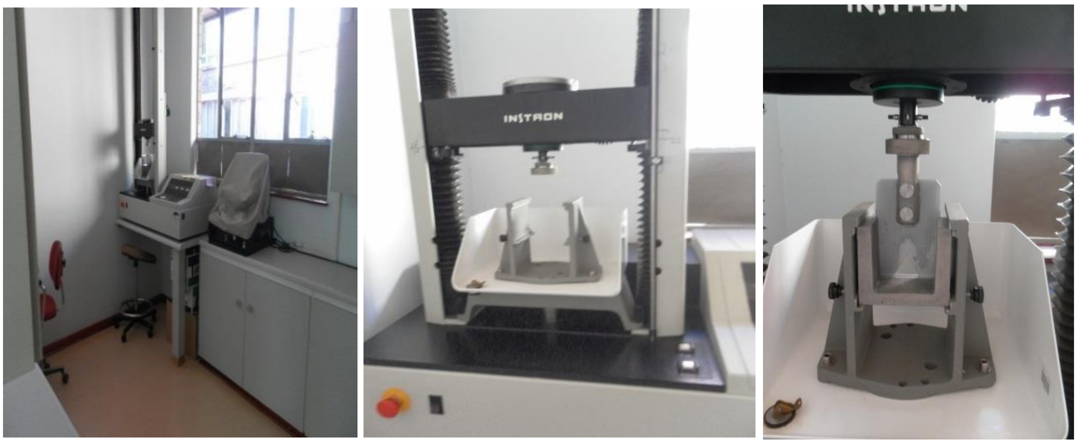

FIGURE 10: WARNER BRATZLER SHEAR FORCE DEVICE

FIGURE 11: CYLINDRICAL CORES OF MEAT

ADDENDUM F

SOUTH AFRICAN CLASSIFICATION OF RED MEAT

SAMIC

Classification of Red Meat*

A key to more effective marketing

PROUDLY SOUTH AFRICAN

Classification provides a sound basis for:

- Meat traders to describe their specific requirements in simple terms when purchasing carcasses.
- Utilisation of variety in the market with a view to optimum consumer satisfaction.
- Utilisation of price differences.
- Determining selling prices.

CLASSIFICATION CHARACTERISTICS OF:
Beef, Lamb, Sheep and Goat Meat

AGE	CLASS
0 Teeth	A
1-2 Teeth	AB
3-6 Teeth	B
More than 6 Teeth	C
FATNESS	**CLASS**
No fat	0
Very lean	1
Lean	2
Medium	3
Fat	4
Slightly overfat	5
Excessively overfat	6

CONFORMATION	CLASS
Very flat	1
Flat	2
Medium	3
Round	4
Very round	5
DAMAGE	**CLASS**
Slight	1
Moderate	2
Severe	3
SEX	
The carcase of a ram or a bull as well as of a hamel, a kapater or an ox showing signs of late castration of the AB, B or C age classes, are identified.	

CLASSIFICATION CHARACTERISTICS OF:
Pork

% MEAT*	mm**	CLASS
≥70	≤12	P
68-69	13-17	O
66-67	18-22	R
64-65	23-27	C
62-63	28-32	U
≤61	>32	S

No specifications in respect of % meat apply in the case of Rough, Sucking pig (≤20kg) and Sausage pig (≥100.1kg).
**In case of Intrascope.

FAT THICKNESS**
% MEAT*
Only in case of the Hennessy classification apparatus.

CONFORMATION	CLASS
Very flat	1
Flat	2
Medium	3
Round	4
Very round	5
DAMAGE	**CLASS**
Slight	1
Moderate	2
Severe	3
SEX	
The carcase of a boar as well as of a barrow showing signs of late castration, are identified.	

*Measured between 2nd and 3rd last rib, 45mm from carcase midline.

MARKS FOR CLASSIFICATION CHARACTERISTICS ON:
Beef, Lamb, Sheep and Goat Carcases

TRAIT	MARK	WHERE ON THE CARCASE
Age (A, AB, B, C)	A AB B C	One mark on each quarter of beef carcase.
Fatness* (0 to 6)	Eg. Class 3 [3]	Only one mark on the carcase for lamb, sheep and goat carcasses.
Conformation (1 to 5)	Eg. Class 3 (3)	One mark on each side of beef carcasses. No mark for lamb, sheep and goat carcasses.
Damage** (1 to 3)	<1> <2> <3>	Taking into account the area of damage, one mark on each side for beef carcasses. Only one mark on the carcase for lamb, sheep and goat carcasses.
Sex	MD	One mark on each side of beef carcasses. Only one mark on the carcase for lamb, sheep and goat carcasses.

* In case of a sheep carcase with a fat tail, a double impression of the mark.
** Damage, if it occurs, is indicated on a scale of one to three for the areas concerned, viz B (buttock), L (loin) and F (forequarter).

MARKS FOR CLASSIFICATION CHARACTERISTICS ON:
Pork Carcases

TRAIT	MARK	WHERE ON THE CARCASE
Conformation (1 to 5)	Eg. Class 3 (3)	One mark on each side.
Damage* (1 to 3)	<1> <2> <3>	Taking into account the area of damage, only one mark on the carcase.
Sex	MD	One mark on each side.

* Damage, if it occurs, is indicated on a scale of 1 to 3 for the areas concerned, viz B (buttock), L (loin) and F (forequarter).

EXAMPLES OF THE ROLLER-MARK COMPOSITIONS FOR:
Beef, Lamb, Sheep and Goat Carcases*

AAA ABAB BBB CCC
000 000 000 000
ZWZ ZWZ ZWZ ZWZ
AAA ABAB BBB CCC
000 000 000 000
ZWZ ZWZ ZWZ ZWZ
AAA ABAB BBB CCC
000 000 000 000
ZWZ ZWZ ZWZ ZWZ
AAA ABAB BBB CCC
000 000 000 000
ZWZ ZWZ ZWZ ZWZ

- Age class of the animal as an indication of tenderness.
The A age class is roller-marked in purple (most tender), AB carcasses are in green (tender), B in brown (less tender) and C in red (least tender)
- Fatness class** of the carcase.
This symbol can be replaced in the roller-mark by 111, 222, 333, 444, 555 or 666.
- Abattoir-identification code.

* All goat carcasses are roller-marked in orange, taking into account the age of the animal (AAA, ABAB, BBB or CCC).

MARKS FOR CLASSES OF PORK:*

CLASS	MARK	WHERE ON THE CARCASE
Sucking pig	S	One mark on forehead.
P, O, R, C, U & S	P, O, R, C, U & S	One mark on each side.
Sausage pig	W	One mark on each buttock.
Rough	RU	One mark on each side.

* The class of a pig carcase is not roller-marked on it. Some pig carcasses may be roller-marked in purple ink with a specific abattoir-identification code/trademark.

SOUTH AFRICAN MEAT INDUSTRY COMPANY (SAMIC)
318 The Hillside, Lynnwood, Pretoria 0081
PO Box 36802, Menlo Park, 0102
Tel: +27 (12) 361 4545 • Fax: +27 (12) 361 9837

*Meat Classification Regulations No. R. 863 in Government Gazette of The Republic of South Africa, 1 September 2006

ADDENDUM G

MASTERSHEET: LOIN

15 days evaluation

8 samples a day

5 repetitions

	1	2	3	4	5	6	7	8
Day 1:								
Abattoir	OKH	OKH	OKH	OKH	OKH	OKH	OKH	OKH
Slaughter date								
Age group	B4	B6	AB2	B6	A2	AB2	AB2	AB3
Aging	55	55	36	36	36	55	55	36
Sample Number	160	132	132	135	237	54	366	49
SE Code	617	238	493	509	231	960	758	290
Day 2:								
Abattoir	OKH	WHK	WKH	OKH	WHK	WHK	OKH	OKH
Slaughter date								
Age group	B4	B4	B6	A3	ABF	B4	A3	A2
Aging	36	36	55	36	36	55	55	55
Sample Number	152	43	198	202L	185	49	199	236
SE Code	150	886	958	227	284	462	984	395
Day 3:								
Abattoir	WHK	WHK	WHK	WHK	WHK	WHK	WHK	WHK
Slaughter date								
Age group	AF	ABG	ABF	AF	B6	AG	ABG	AG
Aging	36	55	55	55	36	36	36	55
Sample Number	213	155	181	215	57	128	154	232
SE Code	443	249	647	552	564	242	891	687
Day 4:								
Abattoir	WHK	OKH	OKH	OKH	OKH	OKH	OKH	OKH
Slaughter date								
Age group	B4	AB2	B4	A2	ABF	AB2	A2	A2
Aging	36	55	55	36	36	36	55	55
Sample Number	49	130	205	203L	183	123	234	201R
SE Code	173	468	359	628	909	670	254	181
Day 5:								
Abattoir	WHK	WHK	OKH	OKH	WHK	OKH	OKH	WHK

Slaughter date								
Age group	AF	AG	AB3	B6	B6	B6	AB3	B4
Aging	36	36	55	36	55	55	36	55
Sample Number	212	196	49	144	51	128	50	47
SE Code	499	381	510	405	567	655	959	123
Day 6:								
Abattoir	WHK	OKH	WHK	OKH	WHK	WHK	WHK	WHK
Slaughter date								
Age group	ABG	A2	ABF	B4	ABG	AG	B6	AF
Aging	55	36	55	36	36	55	36	55
Sample Number	159	239	182	136	155	86	224	214
SE Code	266	627	382	770	854	657	212	350
Day 7:								
Abattoir	OKH	OKH	OKH	OKH	OKH	WHK	WHK	OKH
Slaughter date								
Age group	B4	A2	A2	A2	AG	ABF	ABG	AB2
Aging	55	36	55	201L	55	36	36	55
Sample Number	202	231	200R	36	239	189	156	123
SE Code	528	533	833	403	355	174	869	201
Day 8:								
Abattoir	WHK	OKH	WHK	WHK	OKH	OKH	WHK	OKH
Slaughter date								
Age group	B6	B6	B4	AG	AB4	B6	B6	AB3
Aging	36	55	55	36	36	36	55	55
Sample Number	51	129	46	232	77	132	70	50
SE Code	636	453	700	946	282	563	180	272
Day 9:								
Abattoir	WHK	WHK	WHK	WHK	OKH	WHK	WHK	OKH
Slaughter date								
Age group	ABF	AG	ABG	AF	AB2	B4	AF	B4
Aging	55	55	55	55	36	36	36	36
Sample Number	189	196	162	216	366	47	216	160
SE Code	244	963	890	927	842	174	614	367
Day 10:								
Abattoir	OKH	WHK	OKH	WHK	OKH	OKH	OKH	OKH
Slaughter date								
Age group	AB3	AF	B4	B6	A3	A2	AB2	A2
Aging	55	36	55	36	55	36	36	55
Sample Number	129	214	136	198	202R	200L	130	237

SE Code	710	424	573	829	246	992	592	255
Day 11:								
Abattoir	WHK	WHK	OKH	OKH	WHK	OKH	WHK	OKH
Slaughter date								
Age group	B4	B6	B6	B6	AG	AB3	ABG	AB3
Aging	55	55	55	36	36	55	36	36
Sample Number	43	57	135	128	86	56	162	56
SE Code	569	518	300	375	310	362	370	198
Day 12:								
Abattoir	OKH	WHK	WHK	OKH	WHK	WHK	WHK	WHK
Slaughter date								
Age group	A2	AG	ABF	B4	ABF	AF	AB	B4
Aging	36	55	55	36	36	55	55	36
Sample Number	234	128	183	202	181	212	156	46
SE Code	756	610	997	726	107	184	259	225
Day 13:								
Abattoir	OKH	OKH	OKH	OKH	OKH	WKH	WKH	WKH
Slaughter date								
Age group	A2	A2	B4	AB3	AB2	ABG	AF	B6
Aging	55	55	55	36	55	36	36	36
Sample Number	231	203R	152	129	132	159	215	70
SE Code	414	661	962	905	380	504	671	780
Day 14:								
Abattoir	OKH	WKH	OKH	OKH	WHK	OKH	WHK	WHK
Slaughter date								
Age group	AB4	ABF	B6	B6	B4	AB2	B6	AG
Aging	55	36	55	36	55	36	55	36
Sample Number	77	182	144	129	67	54	224	165
SE Code	166	149	973	581	299	616	791	892
Day 15:								
Abattoir	WHK	WHK	WHK	WHK	WHK	OKH	OKH	OKH
Slaughter date								
Age group	AG	B4	AF	ABF	AB	B4	A3	A2
Aging	55	36	55	55	55	36	36	36
Sample Number	165	67	213	185	154	205	199L	236
SE Code	561	501	186	933	784	753	467	640

ADDENDUM H

MASTERSHEET: RUMP

15 days evaluation
8 samples a day
5 repetitions

	1	2	3	4	5	6	7	8
Day 1:								
Abattoir	WHK	OKH	WHK	WHK	OKH	OKH	OKH	OKH
Slaughter date								
Age group	AF	AB4	AG	ABG	A2	B6	A2	A2
Aging	36	36	36	55	36	55	55	36
Sample Number	215	77	196	159	200L	144	231	239
SE Code	139	256	509	745	375	859	727	955
Day 2:								
Abattoir	OKH	WHK	WHK	WHK	OKH	OKH	OKH	WHK
Slaughter date								
Age group	AB2	B4	ABF	AF	AB2	A2	B4	ABF
Aging	36	36	36	55	55	55	36	55
Sample Number	366	46	181	215	130	200R	152	189
SE Code	121	379	574	487	620	860	721	987
Day 3:								
Abattoir	WHK	WHK	OKH	WHK	WHK	OKH	WHK	OKH
Slaughter date								
Age group	B4	AG	B4	ABG	B6	AB4	B6	B6
Aging	55	55	55	36	36	55	55	36
Sample Number	46	196	205	159	57	77	51	144
SE Code	313	733	525	662	976	218	814	924
Day 4:								
Abattoir	OKH	OKH	WHK	WHK	OKH	OKH	WHK	OKH
Slaughter date								
Age group	A3	B4	B4	B6	AB3	A3	ABG	AB3
Aging	55	36	55	36	55	36	55	36
Sample Number	202R	136	67	70	129	202L	162	49
SE Code	214	927	310	435	573	705	820	940
Day 5:								

Abattoir	OKH	OKH	OKH	WHK	WHK	OKH	WHK	OKH
Slaughter date								
Age group	B4	AB2	AB2	AG	B6	B6	AF	B6
Aging	55	55	36	55	55	36	36	55
Sample Number	160	54	123	86	224	132	213	135
SE Code	157	289	576	632	438	378	873	968
Day 6:								
Abattoir	WHK	WHK	WHK	WHK	OKH	WHK	OKH	WHK
Slaughter date								
Age group	B4	ABF	AF	ABG	A2	ABF	A2	AG
Aging	36	36	55	36	55	55	36	36
Sample Number	67	189	214	155	237	182	234	232
SE Code	327	415	508	584	912	722	844	972
Day 7:								
Abattoir	WHK	WHK	WHK	OKH	WHK	OKH	OKH	OKH
Slaughter date								
Age group	B6	B6	ABG	AB3	AG	B4	B6	AB3
Aging	36	55	55	36	55	36	36	55
Sample Number	198	57	156	50	165	202	135	49
SE Code	303	416	669	772	896	506	160	991
Day 8:								
Abattoir	OKH	OKH	WHK	WHK	OKH	WHK	WHK	OKH
Slaughter date								
Age group	AB2	AB2	B4	ABG	B4	ABF	AF	A2
Aging	55	36	55	36	55	36	36	55
Sample Number	123	54	49	154	136	182	212	236
SE Code	385	449	600	754	197	819	224	960
Day 9:								
Abattoir	OKH	OKH	WHK	OKH	OKH	WHK	WHK	WHK
Slaughter date								
Age group	A2	A3	ABF	B6	A3	B4	AG	AF
Aging	36	36	55	55	55	36	36	55
Sample Number	231	199L	183	129	199R	43	128	216
SE Code	244	457	667	546	333	864	905	155
Day 10:								
Abattoir	OKH	WHK	WHK	OKH	WHK	OKH	WHK	WHK
Slaughter date								
Age group	AB3	B6	ABG	AB2	B6	B6	ABG	ABF

Aging	36	36	36	55	55	36	55	36
Sample Number	129	51	162	366	70	129	155	183
SE Code	470	655	260	781	196	803	950	394
Day 11:								
Abattoir	OKH	OKH	OKH	WHK	WHK	WHK	OKH	OKH
Slaughter date								
Age group	A2	AB2	B6	B4	AG	AF	A2	B4
Aging	36	36	55	55	36	36	55	55
Sample Number	236	130	128	43	165	214	201R	202
SE Code	264	351	453	631	771	788	842	925
Day 12:								
Abattoir	WHK	WHK	OKH	OKH	WHK	OKH	OKH	WHK
Slaughter date								
Age group	B4	AG	AB3	A2	AF	A2	B4	ABF
Aging	36	55	55	55	55	55	36	55
Sample Number	47	128	50	239	215	201L	160	181
SE Code	175	222	402	425	257	535	588	983
Day 13:								
Abattoir	WHK	WHK	OKH	WHK	OKH	OKH	OKH	WHK
Slaughter date								
Age group	ABG	B4	A2	B4	B4	B6	A2	AG
Aging	55	36	36	55	36	55	36	36
Sample Number	154	49	237	47	205	132	203L	86
SE Code	185	334	468	505	522	562	913	933
Day 14:								
Abattoir	WHK	OKH	OKH	OKH	OKH	WHK	OKH	OKH
Slaughter date								
Age group	AF	B4	A2	AB2	A2	ABG	B6	AB3
Aging	55	55	55	55	55	36	36	55
Sample Number	213	152	234	132	203R	156	128	56
SE Code	269	339	575	627	710	737	898	950
Day 15:								
Abattoir	WHK	WHK	OKH	WHK	OKH	WHK	WHK	WHK
Slaughter date								
Age group	ABF	AG	AB2	B6	AB3	ABF	AF	B6
Aging	36	55	36	55	36	55	36	36
Sample Number	185	232	132	198	56	185	216	224
SE Code	885	428	446	633	852	906	945	965

ADDENDUM I

MASTERSHEET: RIB-EYE

15 days evaluation
8 samples a day
8 repetitions

	1	2	3	4	5	6	7	8
Day 1:								
Abattoir	WHK	OKH	OKH	WHK	OKH	WHK	OKH	WHK
Slaughter date								
Age group	B6	AF	B4	AG	ABG	ABG	AG	ABF
Aging	55	55	55	36	36	36	36	55
Sample Number	70	231	205	128	49	156	200L	182
SE Code	124	175	226	277	328	379	429	280
Day 2:								
Abattoir	OKH	WHK	WHK	OKH	WHK	OKH	OKH	WHK
Slaughter date								
Age group	B6	B6	AG	ABF	ABG	ABG	AG	ABF
Aging	36	36	55	36	55	55	55	189
Sample Number	129	70	165	366	155	49	201R	36
SE Code	686	647	786	839	938	742	694	549
Day 3:								
Abattoir	WHK	OKH	WHK	WHK	OKH	OKH	OKH	WHK
Slaughter date								
Age group	B4	B4	B4	AF	ABF	AF	B6	AF
Aging	36	36	55	55	55	36	55	36
Sample Number	47	152	49	212	366	231	128	213
SE Code	114	217	269	320	422	170	222	422
Day 4:								
Abattoir	OKH	WHK	WHK	OKH	WHK	OKH	WHK	OKH
Slaughter date								
Age group	AG	ABG	AG	B4	AF	B6	ABG	ABG
Aging	36	36	36	36	36	36	55	55
Sample Number	201L	162	165	136	214	144	162	50
SE Code	545	598	649	699	748	798	850	900
Day 5:								

Abattoir	OKH	OKH	WHK	OKH	WHK	WHK	WHK	WHK
Slaughter date								
Age group	AG	B4	AG	ABG	B4	B6	ABF	AF
Aging	55	55	55	36	55	36	36	55
Sample Number	203R	202	86	50	46	224	182	214
SE Code	188	142	192	242	292	342	392	442
Day 6:								
Abattoir	OKH	OKH	OKH	WHK	OKH	OKH	WHK	WHK
Slaughter date								
Age group	AF	B6	ABF	B4	AF	ABF	B6	ABF
Aging	55	55	36	36	36	55	55	55
Sample Number	234	135	132	43	234	132	51	183
SE Code	506	556	606	656	706	756	806	856
Day 7:								
Abattoir	WHK	OKH	OKH	OKH	OKH	OKH	WHK	WHK
Slaughter date								
Age group	AF	AF	AG	B6	AG	B6	B6	ABG
Aging	36	36	36	55	55	36	36	36
Sample Number	212	236	203L	129	200R	128	57	159
SE Code	534	583	632	681	730	779	828	877
Day 8:								
Abattoir	WHK	WHK	WHK	OKH	WHK	OKH	WHK	OKH
Slaughter date								
Age group	B6	B4	ABF	B4	AG	ABG	AG	ABF
Aging	55	36	55	55	36	36	55	36
Sample Number	57	67	189	160	232	54	196	130
SE Code	133	183	233	333	383	335	434	238
Day 9:								
Abattoir	WHK	OKH	OKH	OKH	WHK	OKH	WHK	WHK
Slaughter date								
Age group	B4	ABF	AF	ABG	AF	B4	ABF	ABG
Aging	55	55	55	55	55	36	36	55
Sample Number	43	130	236	54	216	160	185	159
SE Code	520	570	620	670	720	770	820	870
Day 10:								
Abattoir	OKH	WHK	WHK	OKH	OKH	OKH	WHK	OKH
Slaughter date								
Age group	AF	AF	AF	B4	ABG	AG	ABG	B6

Aging	55	55	36	55	36	36	55	55
Sample Number	237	215	216	152	56	199L	156	144
SE Code	206	306	159	310	409	214	362	413
Day 11:								
Abattoir	OKH	WHK	WHK	OKH	WHK	WHK	OKH	OKH
Slaughter date								
Age group	ABF	ABF	B6	AG	ABF	B4	ABF	B4
Aging	36	36	36	55	55	55	55	36
Sample Number	123	181	198	199R	181	67	123	205
SE Code	609	759	961	863	765	665	565	513
Day 12:								
Abattoir	WHK	WHK	OKH	WHK	WHK	OKH	WHK	OKH
Slaughter date								
Age group	AG	AG	B6	B4	ABG	AF	B6	ABG
Aging	36	55	36	36	36	36	55	55
Sample Number	86	232	132	46	154	239	224	56
SE Code	542	592	642	692	792	842	892	942
Day 13:								
Abattoir	OKH	OKH	WHK	WHK	OKH	OKH	OKH	OKH
Slaughter date								
Age group	B6	ABF	B4	ABG	ABF	AF	AG	B4
Aging	55	55	36	36	36	55	55	36
Sample Number	132	129	49	155	129	239	202R	202
SE Code	511	561	611	661	711	761	811	861
Day 14:								
Abattoir	WHK	OKH	OKH	WHK	WHK	WHK	WHK	WHK
Slaughter date								
Age group	AF	AF	B4	ABF	ABF	B6	AG	B4
Aging	55	36	55	55	36	36	36	36
Sample Number	213	237	136	185	183	51	196	47
SE Code	145	195	245	295	345	395	445	399
Day 15:								
Abattoir	WHK	OKH	WHK	OKH	WHK	OKH	OKH	WHK
Slaughter date								
Age group	AF	AG	B6	ABG	ABG	ABG	B6	AG
Aging	36	36	55	55	55	36	36	55
Sample Number	215	202L	198	77	154	77	135	128
SE Code	107	157	207	257	307	357	312	163

ADDENDUM J

BEEF CHART