Meat quality of indigenous fat-tail Namaqua Afrikaner, Dorper and the South African Mutton Merino breeds

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained herein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously submitted it, in its entirety or in part, for obtaining any qualification.

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Abstract

This study investigated the carcass composition and yield, physical meat quality attributes, proximate composition and sensory profile of the indigenous, fat-tailed Namaqua Afrikaner (NA) breed and compared it to that of two commercially farmed meat breeds, i.e. the Dorper (D) and the South African Mutton Merino (SAMM). Two crossbred genotypes, namely the NA x D and the SAMM x D were also evaluated.

NA lambs were compared at five months of age with the D and SAMM: with exception of the rib cut, the wholesale meat cuts of the NA contained a lower ($P \leq 0.05$) percentage of meat than those of the D. Apart from the loin cut, the wholesale cuts of the NA were comparable ($P > 0.05$) with those of the SAMM. A lower percentage fat, but a higher percentage bone was recorded in all of the cuts of the NA ($P \leq 0.05$). The same study was repeated with NA and D hoggets. Here the difference between the two breeds in physiological age could be observed. At an older chronological age the NA lean meat yield compared favourably with that of the D ($P > 0.05$). Percentage fat and bone yield of the NA relative to the D were recorded as being lower and higher, respectively ($P \leq 0.05$).

A comparison of the carcass characteristics, physical attributes and nutritional composition of the NA with that of the D, SAMM, NA x D and SAMM x D were conducted over a three year period (2010-2012). Breed differences were observed for slaughter weight, carcass weight, pH, subcutaneous fat depth, cooking loss and percentage moisture content ($P \leq 0.05$) of the *longissimus lumborum* muscle. Attributable to production year, differences were observed in dressing percentage, cooking loss, Warner-Bratzler shear force and percentage moisture content ($P \leq 0.05$). Overall the results of the NA compared favourably with that of the late-maturing SAMM. The intramuscular fat (IMF) content of the NA was significantly less than the purebred breeds (D, SAMM) and crossbred genotypes (NA x D, SAMM x D). No breed differences were observed for shear force (average 49.3 ± 0. 85 N), implying that despite having a lower IMF content (%), the tenderness of the meat of the NA were comparable to the commercial meat breeds.

The sensory profile of the NA meat was compared with that of the D and NA x D cross. No significant differences were reported for lamb aroma; fatty aroma; overall lamb flavour; herbaceous bush-like flavour and aroma; initial and sustained juiciness; metallic taste and residue. The only sensory attribute that differed was tenderness (first bite) with NA having the least tender meat. Tenderness was also highly correlated to other sensory attributes: overall lamb flavour, initial and sustained juiciness, as well as the IMF content (%). It can thus be concluded that the overall sensory profile of the NA did not differ significantly from that of D, except for tenderness.

Since the NA is an unimproved, indigenous breed, it is noteworthy that its meat was mostly comparable with that of the commercial breeds, where traditionally it was presumed inferior. Thus, future research regarding consumer acceptance, as well as investigation of the fatty acid profile of the meat, should be conducted. Further studies should also compare the breeds for production

traits of economic importance to determine whether any breed has advantages in robustness and fitness above other breeds under challenging nutritional and climatic conditions.

Opsomming

Die doel van hierdie studie was om die karkassamestelling en -opbrengs, fisiese vleiskwaliteitseienskappe, voedingswaarde en sensoriese profiel van ŉ inheemse, vetstert skaapras, die Namakwa Afrikaner (NA), te ondersoek en te vergelyk met vleisrasse waarmee kommersieel geboer word, naamlik die Dorper (D) en Suid Afrikaanse Vleis Merino (SAVM). ’n NA x D kruising en SAVM x D kruising is ook geëvalueer as deel van die studie.

NA, D en SAVM lammers is op die ouderdom van vyf maande vergelyk vir karkasopbrengs. Met uitsondering van die ribsnit het die groothandelvleissnitte (boud, lende, skouer) van die NA ’n laer (P ≤ 0.05) persentasie vleis bevat as dié van die D. Benewens die lendesnit, was die groothandelsnitte van die NA vergelykbaar (P > 0.05) met dié van die SAVM. ’n Laer persentasie vet, maar 'n hoër persentasie been is in al die snitte van die NA (P ≤ 0.05) aangeteken. Dieselfde studie is met jaar-oud NA en D lammers herhaal. Op hierdie ouer kronologiese ouderdom was die verskil in fisiologiese ouderdom tussen die twee rasse duidelik sigbaar. Op ’n ouer ouderdom vergelyk die maer-vleisopbrengs van die NA gunstig met dié van die D (P > 0.05). Weereens was die opbrengs van die persentasie vet en been in die NA-karkas opgeteken as onderskeidelik laer en hoër.

Die karkaseienskappe, fisiese vleiskwaliteit en die voedingswaarde van die NA, D, SAVM, NA x D en SAVM x D is oor ’n tydperk van drie jaar nagevors (2010-2012). Rasverskille is waargeneem vir slaggewig, karkasgewig, pH, onderhuidse vetdikte, kookverlies en die persentasie voginhoud (P ≤ 0.05) van die *longissimus lumborum* (LL) spier. Verskille waargeneem in die uitslagpersentasie, kookverlies, Warner-Bratzler skeurkrag (instrumentele sagtheid) en die persentasie voginhoud (P ≤ 0.05) was toeskryfbaar aan die produksiejaar. In die algemeen het die resultate van die NA gunstig vergelyk met dié van SAVM, ook ’n ras wat gereken word as laat-volwasse. Die intramuskulêre vetinhoud (IMV) van die NA was aansienlik minder as dié van beide die suiwer rasse (D, SAVM) en die kruisgeteelde genotipes (NA x D, SAVM x D). Geen rasverskille is aangeteken vir skeurkrag (gemiddeld 49.3 ± 0. 85 N) nie. Dit impliseer dat, ondanks 'n laer IMV inhoud (%), die instrumentele sagtheid van NA vleis gunstig vergelyk met dié van die kommersiële vleisrasse.

Die sensoriese profiel van die NA vleis het gunstig vergelyk met dié van die D en NA x D kruis. Geen beduidende verskille is vir lam-aroma; vetaroma; algehele lamgeur; kruidagtige bossiegeur en -aroma; aanvanklike en volhoubare sappigheid; metaalsmaak en residu gevind nie. Die enigste sensoriese kenmerk waarin ’n rasverskil gevind is, is aanvanklike sagtheid. Die vleis van die NA was die taaiste. Sagtheid was ook hoog gekorreleer met ander sensoriese eienskappe: algehele lamgeur, aanvanklike en volhoubare sappigheid, sowel as die IMV inhoud (%). Daar is dus tot die gevolgtrekking gekom dat die algemene sensories profiel van die NA nie beduidend van dié van die D en NA x D verskil het nie.

Aangesien die NA 'n onverbeterde, inheemse ras is en tradisioneel as minderwaardig beskou word, is dit noemenswaardig dat die vleis daarvan in die algemeen gunstig vergelyk het met dié

van die kommersiële rasse. Dus, toekomstige navorsing kan fokus op verbruikersaanvaarding van die vleis. Verder kan navorsing op die vetsuurprofiel van die vleis gedoen word. Met studies waarin die rasse vergelyk word vir produksie-eienskappe van ekonomiese belang, sal bepaal kan word of die inheemse ras voordele inhou in terme van robuustheid en fiksheid onder beperkende voedingsomstandighede en ongunstige klimaatstoestande.

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And to my parents, for teaching me how to dream.

List of abbreviations

D	Dorper
NA	Namaqua Afrikaner
NA x D	Namaqua Afrikaner x Dorper cross
SAMM	South African Mutton Merino
SAMM x D	South African Mutton Merino x Dorper cross
NSIS	National Small Stock Improvement Scheme
LTL	*Longissimus thoracis et lumborum* muscle
LL	*Longissimus lumborum* muscle
CVD	cardiovascular diseases
CHD	coronary heart disease
N	Newton
g	gram
kg	kilogram
Mt	million tonnes
mm	millimetre
cm	centimetre
ha	hectare
min	minutes
°C	degrees Celsius
NIRS	Near Infrared Spectroscopy
HCW	hot carcass weight
DFD	Dark Firm and Dry meat
IMF	Intramuscular fat
SCF	Subcutaneous fat
SFA	Saturated fatty acid
PUFA	Polyunsaturated fatty acid
MUFA	Monounsaturated fatty acid
pH_{45}	pH at ≈45 min *post mortem*
pH_u	Ultimate pH at ≈48 h *post mortem*
$Temp_{45}$	Temperature at ≈45 min *post mortem*
$Temp_u$	Ultimate temperature at ≈24 h *post mortem*
LSM	Least Squares Means
SE	Standard error
GHG	Greenhouse gasses
GWP	Global warming potential
ADG	Average daily gain

Notes

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

Results from this study have been published as the following:

Burger, A., Hoffman, L.C., Cloete, J.J.E., Muller, M. & Cloete, S.W.P. (2013). Carcass composition of Namaqua Afrikaner, Dorper and SA Mutton Merino ram lambs reared under extensive conditions. *South African Journal of Animal Science*, **43** (5, Supplement 1), S27-S32.

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

Burger, A., Hoffman, L.C., Cloete, J.J.E., Muller, M. & Cloete, S.W.P. (2012). Carcass composition of Namaqua Afrikaner, Dorper and SA Mutton Merino ram lambs. *Proceedings of the 45th Congress of the South African Society of Animal Science,* East London, South Africa. 9-12 July (Presentation).

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Contents

CHAPTER 1

General introduction

Global agricultural production is currently under intense pressure, having to manage the effect of climate change and global warming, coupled with the immense growth seen in the world population (OECD/FAO, 2012; OECD/FAO, 2013; OECD/FAO, 2014). In South Africa, where the majority of the agricultural land is arid or semi-arid, an increase in temperature could result in a loss of the quality and quantity of natural forage for livestock, as well as crops produced for animal feed (Smith *et al.*, 1996; Rust & Rust, 2013). To be able to counteract these threats (Gerber *et al.*, 2013; OECD/FAO, 2013), researchers are currently investigating different scenarios of which farming with indigenous breeds are considered to be a possible solution (FAO, 2003; OECD/FAO, 2012; Montossi *et al.*, 2013). Indigenous breeds are presumably well adapted to their natural habitat, i.e. the prevailing climate and forage species, as well as being adapted to predominant stressors including parasites and diseases (FAO, 2003; Niang *et al*., 2014). In addition, livestock kept in extensive farming systems are directly affected by changes in weather (radiation, wind speed, air temperature, humidity etc.), influencing growth and reproduction abilities (Rust & Rust, 2013).

Sheep farming forms an integral part of small-holder farming in developing countries in Africa, making a contribution to the total income and stability of these regions as well as being an important source of essential nutrients to the human diet (Devendra, 1994; Tshabalala *et al*., 2003). It is predicted that as the weather becomes warmer, farmers will opt to change to livestock species that are better adapted to withstanding heat stress, i.e. small ruminant species (Seo & Mendelsohn, 2008; Rust & Rust, 2013). In South Africa one such indigenous sheep breed (*Ovis aries*) is the fat-tailed *Namaqua Afrikaner*, an endangered species livestock genetic resource (Epstein, 1960; Snyman *et al.* 1993; FAO, 2000; ARC, 2013). It is believed that this breed is a direct descendant of the sheep farmed with by the Namaqua Khoi-Khoi people and considered to be one of the oldest sheep breeds found in South Africa (Epstein, 1960; Ramsay *et al.,* 2001). Development of the Namaqua Afrikaner occurred as a result of natural selection and since this breed fell into commercial obscurity during the 1930's, no selective breeding for the enhancement of commercially valuable attributes (i.e. meat production yield and quality) transpired (Epstein, 1960; Hugo, 1966; Voigt, 1986; Zohary *et al*., 1998; Snyman *et al.*, 2013).

The most prominent feature of the Namaqua Afrikaner is its fat-tail, an adaptive trait to offset nutritional needs in times of drought and forage scarcity (Epstein, 1960). Instead of storing surplus energy in a thick subcutaneous fat (SCF) layer in times of forage abundance, as seen with the imported European and developed composite breeds, the Namaqua Afrikaner stores surplus energy in the fat-tail (Lawrie & Ledward, 2006). Being indigenous to arid and semi-arid regions, developing a thick SCF layer may make the shedding of heat difficult and this may result in the animal suffering from heat stress which has a negative influence on growth and production performance (Lawrie & Ledward, 2006; Rust & Rust, 2013). The Namaqua Afrikaner is adapted to survive on a lower plane of nutrition and its longer legs enables it to travel vast distances in order to find sufficient quantities of nutritious forage (Epstein, 1960; Hugo, 1966; Epstein, 1971; Ramsay *et al.,* 2001; Lawrie & Ledward, 2006). Even though this breed is unimproved and considered wild and "flighty", the Namaqua Afrikaner is also believed to have a greater immunity against diseases and parasites. A recent study by Cloete *et al*. (2013) has provided support for this statement as it was shown that the Namaqua Afrikaner has a greater resistance to ticks, an external parasite.

With meat being one of the major contributors of fat to the human diet, the expected lower intramuscular fat (IMF) content will give the Namaqua Afrikaner meat a competitive advantage in terms of nutritional composition. Health benefits of the meat could possibly be promoted as the general health-conscious consumer is currently favouring lean red meat – an attribute, if marketed appropriately, could be beneficial to the producer, processor and end consumer. According to anecdotal data, it is believed that the fatty acid profile of the Namaqua Afrikaner meat will have a more beneficial polyunsaturated fatty acid (PUFA) to saturated fatty acid (SFA) ratio (P:S ratio) than the meat breeds currently farmed with. Research has shown that with a decrease in IMF content, the P:S ratio of the meat increases (Strasburg *et al.*, 2008; Webb & O'Neill, 2008). Furthermore, meat is regarded as being nutrient dense, i.e. it is a source of the essential nutrients required for sustaining a healthy lifestyle (Biesalski, 2005; Elango *et al.*, 2012; Binnie *et al.*, 2014). Meat significantly adds to the pool of essential micronutrients, i.e. vitamins A and B (thiamine, riboflavin, B12) and minerals (iron; zinc, selenium, potassium), it is also considered a source of high quality proteins (Warriss, 2000; Biesalski, 2005; Wyness *et al.*, 2011; Binnie *et al.*, 2014).

Unfortunately the lower IMF content of the Namaqua Afrikaner meat, in conjunction with this animal's wild and "flighty" nature, could result in the meat having a higher pH_u (Priolo *et al.*, 2001; Honikel, 2004; Cloete *et al.*, 2005). When exposed to stressful stimulus, i.e. pre-slaughter stress, a lower glycolytic potential could be created, resulting in possible glycogen depletion and thus a high pH_u (> 6.0) (Priolo *et al.*, 2001; Honikel, 2004; Cloete *et al.*, 2005). Showing signs of being dark-firm-dry (DFD) at the retailer will negatively impact upon the meat's visual appearance, together with the shelf-life stability thereof. Colour, visible exudate in the packaging, as well as visible fat (marbling and SCF) are important quality cues used by consumers to judge the quality and freshness of the meat upon purchase (Grunert *et al.*, 2004; Troy & Kerry, 2010). Furthermore, the sensory profile (aroma, flavour, tenderness and juiciness) of the meat is an important feature when purchasing meat. However, when selecting in favour of a lower IMF content, selection against palatability takes place, clearly indicating the trade-off effect that exists between palatability and IMF content (Warriss, 2000; Webb & O'Neill, 2008; Jacob & Pethick, 2014).

As meat production essentially revolves around profit, the percentage lean meat yield that can be obtained from a single carcass is very important to the producer, as well as to the end consumer. The same can be postulated for the time taken by the lambs to reach a viable slaughter weight. Traditionally indigenous species are believed to produce carcasses with an inferior meat yield (Tshabalala *et al.*, 2003). Being late maturing, the Namaqua Afrikaner lamb will take longer to reach physiological maturity in comparison with early maturing breeds. This implies that the late maturing Namaqua Afrikaner will only be slaughter ready at an older chronological age. Furthermore, during the 1930's, the Dorper breed was developed as the carcass conformation of the Namaqua Afrikaner was not favoured by international consumers (Campbell, 1980; as cited by De Waal & Combrinck, 2000; Nel 1993; Milne, 2000).

At present the early maturing Dorper is South Africa's main meat breed and is considered to have good meat quality and carcass characteristics. A disadvantage of the Dorper, as a result of its early maturing nature, is that it could possibly become too fat. The late maturing South African Mutton Merino (SAMM) is the main dual-purpose breed farmed with in South Africa, and its carcass should contain less fat when slaughtered at the same chronological age (Webb and Casey, 1995; Milne, 2000; Cloete *et al.*, 2007). Snyman *et al*. (1996) reported that while the monetary yield on Namaqua Afrikaner carcasses might be smaller than that of the commercial breeds (Dorper and Afrino) when sufficient grazing is available; under severe droughts the Namaqua Afrikaner outperforms these breeds. In their study the commercial breeds were provided with additional feed to supplement available pasture, raising farming costs. However, it was not necessary to supplement the paddocks utilised by the Namaqua Afrikaner, and it still outperformed the latter breeds, highlighting the hardiness of the Namaqua Afrikaner and its ability to withstand nutritional strain (Snyman *et al.*, 1996).

In addition, it might be possible to combine the hardiness of the Namaqua Afrikaner with the meat quality potential of the Dorper and SAMM. Therefore crossbreeding will also be investigated in this study, as crossbred genotypes are known to express hybrid vigour (Fogarty, 2006) and also to combine favourable attributes of the parent breeds.

At present limited information regarding the meat quality attributes and carcass yield of the Namaqua Afrikaner is available. Therefore the objective of this study was to investigate and compare the Namaqua Afrikaner to the purebred Dorper and SAMM, as well as two crossbred genotypes, namely the Namaqua Afrikaner x Dorper (NA x D) and the SAMM x Dorper (SAMM x D) in terms of the influence of breed on the following:

- Carcass composition and lean meat yield of lambs at an average of five months of age;
- Carcass composition and lean meat yield of hoggets at an average of 16 months of age;
- Carcass characteristics (slaughter weight and dressing percentage);
- Physical meat quality attributes (pH, SCF depth, drip loss, cooking loss, colour and instrumental tenderness) of the *longissimus et lumborum* muscle;
- Proximate composition (moisture, protein, fat and ash content) of the *longissimus et lumborum* muscle;
- Sensory attributes (aroma, flavour, sensory tenderness and juiciness) of the *longissimus et lumborum* muscle.

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CHAPTER 2

Literature review

2.1 Background

According to calculations by the Food and Agriculture Organization (FAO) of the United Nations (UN) over 900 million people do not have access to adequate amounts of nutritious food at present (OECD/FAO, 2012). Predictions indicate that the fast growing world population will increase from the current 7 billion to 9.1 billion people by 2050, an increase of more than 2 billion people (34%) in less than 40 years. Calculations indicate that this population growth will mainly occur in developing countries, with the least developed countries showing the highest growth (OECD/FAO, 2012).

Countries in sub-Saharan Africa will especially show a marked increase in population growth by 2050 (FAO, 2006). It is estimated that the aggregate number of people added by 2050 will be 26 million per annum, of which 18 million will be from sub-Saharan Africa. The total population of some African countries will thus have doubled by 2050 (FAO, 2006).

Not only is the global population expanding at such a rapid pace, at the same time rural migration is also accelerating (OECD/FAO, 2012; OECD/FAO, 2013; OECD/FAO, 2014). As a result of the accelerated rural migration 66% of the world's population will be residing in urban areas by 2050, in contrast to the present day figure of 50% (UN, 2014). Furthermore, as urbanisation continues potential agricultural land is diminishing and thus not available for agricultural production, but at the same time a significantly greater segment of the human population will be dependent on purchased instead of home grown food (OECD/FAO, 2012; OECD/FAO, 2013).

In developing countries in Asia and sub-Saharan Africa a general increase in income has been noted and it is evident that a larger percentage of the disposable income is available to be spent on the "food basket" – in particular protein-rich foods (OECD/FAO, 2012; OECD/FAO, 2013; Henchion *et al.*, 2014). Having more funds available to spend will open up the prospects for many consumers to improve their standards of living and allow them to buy modern appliances, such as refrigerators, resulting in a change in the demand for fresh meat. According to the FAO these changes in diet patterns, linked to urbanisation and the population growth, will have a critical influence on the agricultural sector and unmistakably on the environment as well (OECD/FAO, 2012; OECD/FAO, 2013).

As a result of the rate at which population growth is occurring, obstacles to achieving global food security could be expected (FAO, 2006; OECD/FAO, 2012; OECD/FAO, 2013). To be able to meet the rapidly, ever-growing demand for food, the total global agricultural production will have to increase by at least 60% by 2050 if evaluated against the 2005/2007 production scale

(OECD/FAO, 2012). In the meat industry alone production will have to increase with another 200 million tons per annum (OECD/FAO, 2013).

2.2 Meat consumption: globally and in South Africa

Research by the FAO (2012) shows that the global meat balance for 2011 stood at 297.2 Mt of which only 13.5 Mt were ovine meat (FAO, 2012). Forecasts indicate that in 2014 the global meat balance will increase to 311.8 Mt and global ovine meat production to 14.0 Mt (FAO, 2014). However, despite the increasing demand, it is anticipated that meat production will grow at a slower rate than in the preceding decade and between 2014 and 2023 growth, in general, is expected to decline from 2.3% p.a. to 1.6% p.a. (OECD/FAO, 2013; OECD/FAO, 2014). Most of the decline in production will be seen in the poultry industry, which was also responsible for the highest production growth in previous years. Growth in the meat production sector is mainly seen in the developing countries and their contributions to the global "meat basket" are expected to be 80% of production by 2022 (OECD/FAO, 2013). It is further predicted that bovine and sheep meat production will increase more rapidly by 2023 (2014-2023) than in the previous decade (OECD/FAO, 2014).

In comparison to the other agricultural commodities, the global consumption of meat is still showing one of the highest growth rates, although a deceleration in growth is also expected (OECD/FAO, 2013). Recent predictions indicate that after a decade of decline, growth in meat consumption is expected in developed countries such as the United States and certain European countries (OECD/FAO, 2014). In developing countries consumption will grow with 10% *per capita* by 2022, when compared to the base period of 2010-2012 (OECD/FAO, 2013); and are expected to account for 83% of the total increase in consumption by 2023 (OECD/FAO, 2014). In Africa specifically, consumption growth has been rapid over the last 10 years, but consumption *per capita* is still standing at a low 34% of the total global average. Even so, the projected rapid growth in the human population will result in a substantial increase in total meat consumption in African countries, with mutton/lamb expected to account for 20% of this total (OECD/FAO, 2014).

Declines evident in both global production and consumption growth rates are not only related to high feed and energy costs associated with livestock production, but are also due to possible disputes arising over available (arable) land and water (OECD/FAO, 2013). The only way to ensure food safety, to keep prices low and increase production will be through optimising the production chain itself, while improving sustainable use of resources such as water and land (OECD/FAO, 2012). Again, the majority of these improvements will be taking place in developing countries where there is still a vast scope for improvement in breeding and herd/flock management practices, while simultaneously addressing the needs of pastoralists (OECD/FAO, 2013).

The current 5% global market share of sheep meat is predicted to grow with 1.6% p.a. to 16 Mt by 2022 (OECD/FAO, 2013). Of the almost 14.0 Mt of sheep meat produced annually around the globe, only 140.2 thousand tons of mutton/lamb is produced within South Africa (DAFF, 2012;

FAO, 2014). According to the 2011/2012 records of the Department of Agriculture, Forestry and Fisheries (DAFF) production of sheep meat in South Africa shows a consistent shortfall and thus the country is considered a net importer of mutton/lamb. Over the 2011/2012 period the total consumption of mutton/lamb/goat was 149 000 tons, with a net import of 10 100 tons (DAFF, 2012). However, according to the latest information published by DAFF (2014) the South African red meat sector is seen as a vitally important growing industry – an increase of 11.8% in lamb and mutton production and 9.6% in consumption was observed over the last year (2012/2013), while imports decreased with 38.4% (DAFF, 2014) – with predictions indicating that this upward trend will last in the long term enabling supply to meet demand in the consumption of meat (BFAP, 2013).

At the same time there are several concerns on the subject of the contribution of livestock production to the occurrence of global warming, as well as the detrimental effects of global warming on the agricultural sector (Steinfeld *et al.,* 2006a). Although the global increase in meat production is decelerating, the demand for meat and meat products are increasing, even if at a slower rate, and it is therefore important to improve the efficiency of livestock production systems. The entire food and agricultural sector is a major contributor to the greenhouse effect. Anthropogenic emissions of GHGs can be found throughout the production as well as the consumption process (Steinfeld *et al.,* 2006a).

In general the current predictions regarding the effects and influences of global warming is alarming, but there is a lot of controversy about what exactly can be attributed to the anthropogenic effects of global warming. However, for the scope of this study it was decided to accept these negative predictions and use it as a starting point. The contribution of livestock to global warming and the effect of global warming on livestock production will be discussed throughout this chapter, as part of the relevant sub-sections.

2.3 Climate change and global warming

According to the Oxford Dictionary of Science (2010) climate change can be defined as:

> *"A long-term change in the elements of climate, such as temperature, precipitation, wind and pressure, measured over a period of time of at least several decades".*

When reviewing the geological history of the earth, it is clear that changes in the climate are inevitable and that the earth is experiencing alternating glacial and inter-glacial periods (Bowman, 1990; Steinfeld *et al.,* 2006a). Although there are several biogenic aspects influencing the mechanisms of climate change, the contribution of anthropogenic (man-made) factors are accelerating the process at an unnaturally rapid rate (Steinfeld *et al.,* 2006a; Raven *et al.*, 2007). One of the main causes is the increase in emissions of anthropogenic greenhouse gasses (GHG) into the atmosphere, creating a greenhouse effect and leading to the exacerbation of global warming (Bowman, 1990; Steinfeld *et al.,* 2006a; Raven *et al.*, 2007).

Global warming is regarded as a steady rise in earth's average air temperature over a specific period of time, as a result of changes in the composition of the atmosphere (Oxford Dictionary of Science, 2010). This phenomenon is attributed to the existence of greenhouse gasses (GHG) in the earth's atmosphere (Steinfeld *et al.,* 2006a; Ben Salem *et al*., 2011). The primary gasses involved in the greenhouse effect are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) (Steinfeld *et al.,* 2006a; Ben Salem *et al*., 2011). According to the Intergovernmental Panel on Climate Change (IPCC) (2001) (as cited by Pitesky *et al.,* 2009) the Global Warming Potential (GWP) of CO_2 is used as a reference standard in the determination of the GWP of other GHGs. One unit of heat is absorbed by one unit of CO_2 in the atmosphere (IPCC, 2001; as cited by Pitesky *et al.,* 2009; Webb, 2013). Thus the GWP of a GHG can be referred to as the percentage of heat absorbed by one unit of the specific GHG in comparison with the amount of heat absorbed by one unit of CO_2, measured over a defined period of time. The GWP of CH_4 measured over a period of 100 years is between 21 and 23 times that of CO_2 and the GWP of N_2O 296 times more than CO_2. For ease of reference these values are pooled and are generally indicated in terms of CO_2 equivalents (IPCC, 2001; as cited by Pitesky *et al.,* 2009; Steinfeld *et al.,* 2006a; Webb, 2013).

The greenhouse effect is in fact a natural occurrence, essential in the regulation of the earth's temperature (Moss *et al.,* 2000). The earth receives solar energy in the form of visible light (0.4 to 0.7 µm) and ultraviolet radiation (below 0.4 µm) from the sun and reflects it back into the atmosphere in the form of infrared rays (4 to100 µm) (Gribbin, 1988; as cited by Moss *et al.,* 2000). The incoming short-wave rays are not absorbed by the GHGs, but the longer wavelengths of the infrared rays place them within the absorption band of the GHGs. Heat is thus trapped within the lower layer of the atmosphere (troposphere), radiated back towards the earth and a greenhouse effect is created. Without the greenhouse effect the surface temperature of the earth would not support life as we know it and would be between 21°C and 30°C colder than the current average of 15°C (Gribbin, 1988; as cited by Moss *et al.,* 2000; Steinfeld *et al.,* 2006a).

However, since the industrial revolution during the 18th and 19th centuries emissions of anthropogenic GHGs have increased notably (Siegenthaler *et al.,* 2005; IPCC, 2007). The IPCC (1997) has found that since 1750 the concentration of CO_2 has risen from 280 to 379 ppm, CH_4 from 715 to 1732 ppb and N_2O from 270 ppb to 319 ppb. The mean surface temperature of the earth has risen with approximately 0.6°C in the last 150 years and research by the United Nations (UN) point towards an additional temperature increase of between 1.4 and 5.8°C by 2100 (IPCC, 1997; UNFCCC, 2005). Siegenthaler *et al.* (2005) and Padodara and Jacob (2013) noted that the present day concentration of carbon dioxide in the earth's atmosphere is higher than ever before throughout the last 650 000 years.

Apart from the rise in average temperature, it is anticipated that global warming will have a severe effect on the earth's environment and ecosystems (Steinfeld *et al.,* 2006a). The warmer weather is predicted to melt the polar icecaps, glaciers and permafrost resulting in a rise in sea level of approximately 9-88 cm within the next century (IPCC, 2001). Changes in global rainfall patterns and the average yearly precipitation, the occurrence of heat waves, droughts, storms and floods as well as the intensity and frequency of these extreme weather events are expected. As a result of global warming shifts in temperature zones will occur, impacting on ecosystems and biomes. As natural selection to adapt to these changes does not occur at the same speed at which global warming is occurring, it could result in extinction of plant and animal species (IPCC, 2001; Steinfeld *et al.,* 2006a; Raven *et al.*, 2007).

2.4 Global warming and the agricultural sector

Although the entire food production process is a major contributor of GHGs, livestock farming is in the unfortunate position where it not only contributes to global warming, but at the same time suffers greatly from the consequences thereof (Aydinalp & Cresser, 2008; Hoffmann, 2010; Ben Salem *et al*., 2011; Rust & Rust, 2013). Recent recommendations by the FAO (Gerber *et al.*, 2013) thus focus on the possibilities of appropriately managed livestock production playing a significant role in the necessary climate change/global warming mitigation effort.

2.4.1 The effect of livestock production on global warming

Contributing to the emissions of GHGs livestock, and in particular ruminants, are escalating the effect of anthropogenic global warming (Steinfeld *et al.,* 2006a). Their contribution to the greenhouse effect can either be primary or secondary (Ben Salem *et al*., 2011; Gerber *et al.*, 2013). Primary or direct contributions would include emissions of GHGs (CH_4 and N_2O) as part of enteric fermentation and manure. Methane (CH_4) is produced during the fermentation process in the rumen as a by-product of the digestion of organic materials (Jungbluth *et al.,* 2001; Ben Salem *et al*., 2011; Gerber *et al.*, 2013).

Secondary or indirect contributions would be in the form of emissions of GHGs produced during the production of crop for feed and the manufacturing of feed (Mosier *et al.,* 1996; Gerber *et al.*, 2013). Carbon dioxide is released during the transport of livestock as well as during the transportation of refrigerated livestock products when fossil fuels are burned for fuel (Mosier *et al.,* 1996; Gerber *et al*., 2013).

The UN estimated that the total contribution of GHGs from the livestock sector is standing at 18% of total GHG emissions (Steinfeld *et al.,* 2006b), even higher than emissions from the Transport sector. However, the accuracy of the results was widely questioned and recent research has brought to light that although the livestock industry does contribute to global warming, the projected 18% is vastly over-estimated (Webb, 2013). The latest report from the FAO (Gerber *et al.*, 2013) implicated the livestock sector in 14.5% (7.1 Giga ton) of the anthropogenic GHGs – with sheep standing at 6% of this figure or 0.9% of livestock anthropogenic GHGs. Several mitigation propositions proposed by the FAO (2014) can be employed to alter and greatly reduce these figures. Possible mitigation ideas include (Gerber *et al.*, 2013; FAO, 2014):

- improving the digestibility of feed, while improving feed practices, resulting in a reduced quantity of methane being produced through enteric fermentation;
- improving animal health;
- improving animal performance through genetic selection;
- increasing herd numbers included in production, while decreasing number of animals kept for herd maintenance;
- better management of grazing practices;
- implementing the use of energy saving equipment and other practices – throughout the production chain;
- increasing recycling, reducing waste;
- changing to the use of feed with low emission intensity.

However, being global averages, these numbers are not representative of any specific region and/or production system – making it difficult to properly employ mitigation plans, as these have to be tailored to the specific area's needs (Capper, 2013; FAO, 2014).

2.4.2 The effect of global warming on livestock production

The effect of global warming on the agricultural sector is of great concern and although the impact thereof will differ greatly across different regions and environments, the influence of global warming is evident everywhere and will be the worst in arid and semi-arid regions (Thornton *et al.,* 2007). In these regions, where land and other resources are already under pressure, the situation could be intensified if possible disputes over available land, crops and water resources break out (Ben Salem *et al*., 2011; Rust & Rust, 2013). The pressure would be at its highest in developing countries where food scarcity is already a concern and in arid and semi-arid regions this situation will be further exacerbated (Steinfeld *et al.,* 2006a; OECD/FAO, 2013).

Most of the global pastoral systems are located in Africa, Asia and Australia of which 3 billion hectares can be found in arid regions (Nardone *et al.,* 2010). In general the domestic animals farmed with in these regions are ruminants, producing around 30% of the total world small ruminant meat and 20% of the total world beef (Nardone *et al.,* 2010).

Applying a structural Ricardian model, measuring the influence of climate change on African livestock management, it has been suggested that the impact of climate change will be brutal (Seo & Mendelsohn, 2008). In developing countries, where animals are kept outdoors in extensive or pasture grazing systems and thus exposed to the elements, livestock farming will be particularly sensitive to changes in the climate (Rust & Rust, 2013). Growth, milk and wool production and reproduction abilities of animals will be directly influenced by changes in radiation; air temperature, humidity, wind speed etc. (Rust & Rust, 2013) with beef cattle farming being challenged the most (Seo & Mendelsohn, 2008). Furthermore, changes in the climate will also affect the availability and quality of natural grazing and influence the production, quality, quantity and prices of crop destined for animal feed production (Smith *et al.*, 1996; Rust & Rust, 2013). Changes in the type and frequency of diseases and pests are also to be expected (Niang *et al.*, 2014).

Small ruminants forms a central part of small-holder farming systems in Africa, contributing to the total income and stability of these systems as well as being an important source of human nutrition (Devendra, 1994; Tshabalala *et al.*, 2003). It is expected that livestock farmers will choose the livestock species, as well as the flock/herd size, through which profit margins can be optimised (Seo & Mendelsohn, 2008). Research shows that as temperature increases farmers are selecting the better adapted sheep and goat breeds, while as precipitation increases the number of goats and chickens farmed with increase. Furthermore, according to Seo and Mendelsohn (2008), as temperatures rise, not only will more farmers change to farming with small ruminants, but the number of animals kept will also increase.

2.4.3 South African agriculture and global warming

The vast majority of South African land surface is located in either arid or semi-arid regions, limiting possible agricultural production to pastoral use (Fig. 2.1) (Cloete & Olivier, 2010). Total land surface area equals 105.2 million hectares, with 86.2 million hectares being utilised by the agricultural sector. Already more than 80% of the allocated farm land can only be used for extensive livestock farming systems (Cloete & Olivier, 2010). It is already accepted that the climate is getting warmer and drier in the southern part of Africa (Meissner *et al.*, 2013).

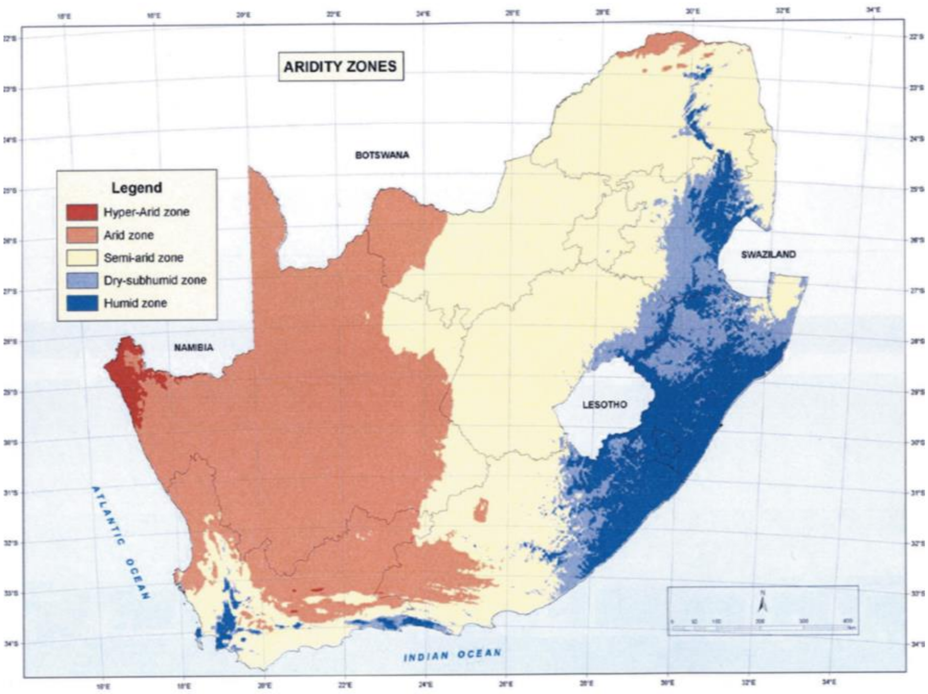


Figure 2.1 Global humidity index for South Africa (AGIS, 2007); as cited by Cloete and Olivier (2010).

The South African ruminant livestock production can be divided into two segments: commercial (intensive and extensive) and subsistence (emerging and communal) farming (Du Toit *et al.*, 2013). In 2010 South African small stock was responsible for 207.7 Giga grams methane emission, ≈15.6% of the total South African livestock emissions, with sheep contributing 167 Giga grams to this figure – of which ≈91% is contributed by emissions from commercial sheep flocks (Du Toit *et al.*, 2013). Attributable to weather changes tending towards a drier climate in the south-western parts of South Africa, the natural food resources of livestock are forecast to diminish (Turpie *et al.*, 2002; Vetter, 2009; West *et al.*, 2009; Willis & Bhagwat, 2009; Pio *et al.*, 2014). This changing scenario is expected to result in challenges to small stock farming as far as adaptation of animals to the changing environment and the sustainability of farming is concerned – eventually influencing the quantity and quality of food (meat) produced (Ben Salem *et al*., 2011; Meissner *et al.*, 2013).

2.5 Indigenous breeds

Changes to national and international consumer demands during the early 20th century have resulted in the replacement of the indigenous fat-tailed breeds then farmed with in South Africa, with imported mutton breeds (Campbell, 1980; as cited by De Waal & Combrinck, 2000; Nel, 1993; Milne, 2000). Therefore, very little to no research has been conducted on the indigenous breeds until quite recently and it was presumed that the indigenous breeds are inferior to the imported breeds (FAO, 2003). The imported breeds and composite breeds have been developed through selective breeding with the enhancement of economically viable traits in mind; including higher carcass yields and the improvement of the organoleptic qualities of the meat (FAO, 2003).

Facing the difficulties of having to optimise food production but at the same time being handicapped by limitations in the use and availability of agricultural land coupled with a warmer climate (OECD/FAO, 2013; Gerber *et al.*, 2013), the possibility of farming with indigenous species using modern technologies has become a potential solution. A growing interest amongst research communities in such breeds have been noted (FAO, 2003; OECD/FAO, 2012; Montossi *et al.*, 2013).

Furthermore imported breeds are not well adapted against droughts and do not have a high level of immunity against diseases and parasites and would require an intense labour and financial involvement in terms of additional feed and vaccinations (FAO, 2003). Indigenous breeds, such as the fat-tailed sheep, are highly adapted to their surroundings (FAO, 2003). They are well known for their ability to withstand high temperatures, being able to live on a low plane of nutrition in times of scarcity and drought – reducing the effects of heat stress and forage scarcity on the quality of meat produced (FAO, 2003). Therefore, by optimally applying indigenous animal genetic resources, it could be possible to ensure sustainable sheep production under adverse conditions.

There are a number of indigenous fat-tailed sheep in South Africa that may have the potential to become more viable under the warmer climate expected and need to be studied further. These breeds include the Nguni, Tswana, Pedi, Sabi, Damara, Karakul and particularly the Namaqua Afrikaner sheep breeds (Almeida, 2011a).

2.6 Namaqua Afrikaner

The Namaqua Afrikaner is a fat-tailed sheep, indigenous to South Africa and is regarded as a national heritage (Epstein, 1960; ARC, 2013). According to the Agricultural Research Council (ARC) (2013) and Snyman *et al.* (1993) it is one of the oldest sheep breeds found within South Africa.

The ancestors of the Namaqua Afrikaner sheep can be traced back to the fat-tailed sheep owned by the northern Namaqua Khoi-Khoi or Nama people (Epstein, 1960; Willcox, 1966; Ramsay *et al.,* 2001). When the Khoi-Khoi migrated to Southern Africa, between 200 and 400 AD, livestock was brought with, including the fat-tailed sheep they farmed with (Ramsay *et al.,* 2001). After migrating south the Khoi-Khoi settled in the northern parts of the current day Western Cape and Northern Cape, as well as the southern region of current day Namibia (Epstein, 1960; Ramsay *et al.,* 2001). Research has found several similarities between the fat-tailed sheep of the Namaqua Khoi-Khoi and the fat-tailed Namaqua Afrikaner, establishing common ancestry (Epstein, 1960; Willcox, 1966). The development of the Namaqua Afrikaner took place through natural selection, and to some extent unconscious selection, and thus the Namaqua Afrikaner's development was not enhanced through commercial breeding to optimise meat production (Epstein, 1960; Hugo, 1966; Voigt, 1986; Zohary *et al*., 1998; Snyman *et al.*, 2013). Buduram (2004) notes that the Namaqua Afrikaner express very little polymorphism and is genetically different from the other indigenous and developed breeds, including the Dorper.

The most favourable attribute of the Namaqua Afrikaner is it's adaptation to harsh temperature conditions, such as experienced in the arid and semi-arid regions in South Africa (Fig. 2.1) (Epstein, 1960; Hugo, 1966; Epstein, 1971; Campbell, 1995; Ramsay *et al.,* 2001; Cloete & Olivier, 2010). It is not a labour intensive breed and can survive extreme infra-red radiation during the day as well as extreme cold night temperatures when reared under extensive conditions (Ramsay *et al.,* 2001). Colouring of an animal's coat is a well-known adaptation to temperature control. In tropical regions the colouring of an animal is more often light (Lawrie & Ledward, 2006a). Radiant energy is more easily absorbed by dark colours, therefore the adaptation towards a lighter coat. In studies done on cattle it has been shown that a lighter coloured (white, yellow or red) coat absorbs less heat, particularly if the coat has a smooth and glossy texture (Lawrie & Ledward, 2006a). The coat of the Namaqua Afrikaner conforms to this statement: instead of having a coat of wool it has light coloured coat, consisting of smooth and shiny hair, (Mason & Maule, 1960), with a reddish brown or black head – the *spotted* gene of the *Spotting* locus is often visible, where the white extends towards the crown of the head (Lundie, 2011). The coat is shed instead of shorn during the early summer months, but under drought conditions it is retained (Mason & Maule, 1960; Epstein, 1971).

Previous research also indicates that the Namaqua Afrikaner ewes have good mothering abilities and are able to rear a 90% lamb crop under high temperatures and arid conditions with a precipitation of less than 150 mm p.a. (Mason & Maule, 1960). Snyman *et al.* (1993) found that the lambs have the ability to maintain high pre-weaning growth rates under the same conditions, while the reproductive performance of the ewes compare favourably with other breeds including the Dorper and South African Mutton Merino (SAMM).

Indigenous breeds are better adapted to their surroundings, believed to include a better level of immunity/resistance against predominant diseases and parasites (FAO, 2003; Almeida, 2011b). Very little information is available in literature regarding the immunity of the Namaqua Afrikaner, but according to anecdotal data this breed is presumed to be more robust and better adapted to withstanding diseases and parasites. A recent study by Cloete *et al.* (2013a) suggested that the Namaqua Afrikaner can withstand tick infestations better than both the Dorper and SAMM breeds in an extensive farming system; under high tick burdens. These results of Cloete *et al*. (2013a) are very important as one of the FAO's (2014) climate change mitigation propositions are specifically the achievement of better animal health.

The Namaqua Afrikaner has long, slender legs – well adapted to frequently walking vast distances in the search of grazing and water under harsh conditions (Epstein, 1960; Hugo, 1966; Epstein, 1971; Ramsay *et al.,* 2001; Lawrie & Ledward, 2006a). Snyman *et al.* (1996a) found that on comparison to a Dorper the body of the Namaqua Afrikaner is longer and narrower, whereas the Dorper has a more square body conformation (Refer Chapter 4; Fig 4.2). The Namaqua Afrikaner is a late-maturing breed and a subcutaneous layer of fat will only develop after an extended period of time (Epstein, 1960; Mason & Maule, 1960; Epstein, 1971).

Body fat is mostly accumulated in the fat-tail and therefore fat deposits in the loin (*longissimus thoracis et lumborum*) and the rest of the body are minor (Epstein, 1960). The biological functionality of the fat-tail of the Namaqua Afrikaner has on occasion been compared to that of the hump of a camel (Almeida, 2011b). The fat-tail acts as a depot for reserve fat and nutritional reserves when food is abundant and can be utilised during times of drought or when migrating. Furthermore, developing a subcutaneous layer of fat (SCF), used for insulation, would make the shedding of heat too difficult and would reduce the survival rates of animals in hot and humid environments (Lawrie & Ledward, 2006a). This is an adaptive response of the Namaqua Afrikaner in answer to the harsh environmental conditions of high temperatures and low forage availability and can thus prevent unnecessary weight loss when utilising the reserves for survival (Lawrie & Ledward, 2006a; Almeida, 2011a).

According to Bisschop *et al.* (1954) (as cited by Epstein, 1971) the fat-tail of the Namaqua Afrikaner weighs on average between 2 kg and 4.5 kg, but can reach up to 7 kg for some animals – and could equal up to 38% of the total body fat (Snyman *et al.,* 1993). The tail is long, divided into three distinct sections, with a spiral-like twist or curl to either the left or the right side (Bisschop *et al.,* 1954; as cited by Epstein, 1971; Qwabe *et al*., 2013). Qwabe *et al*. (2013) has found that

60% of the time the twist would be to the left and it was noted by Campbell (1995) that the tail of the Namaqua Afrikaner differs from that of other fat-tailed breeds – the fat-tails of other breeds do not have a twist but is long and straight.

The fat-tail can also be promoted as a value-adding trait in the processed meat industry (Ramsay *et al.,* 2001). According to anecdotal data the fat-tail of the Namaqua Afrikaner contains a higher quantity of unsaturated fatty acids compared to the tails of thin-tailed breeds (e.g. Dorper and SAMM). At present there is no literature available on the fatty acid profile of the Namaqua Afrikaner, but Yousefi *et al.* (2012) recently published results on a similar study done on the indigenous fat-tailed Chall and thin-tailed Zel sheep of Iran. Results for the analysis done on the *longissimus thoracis et lumborum* samples indicated that the Chall lambs had a significantly lower intramuscular fat concentration than the Zel lambs ($P < 0.01$). In addition differences were also found in the fatty acid profile itself – samples from the Chall lambs contained less monounsaturated fatty acids (MUFA) ($P < 0.01$) and more polyunsaturated fatty acids (PUFA) ($P < 0.05$). Also, the ratio of PUFA to saturated fatty acids (P:S) and n-3 PUFA of the Chall were significantly higher ($P < 0.05$), while the n-6:n-3 PUFA of the Chall lambs (4.77 ± 0.35) were lower than that of the Zel lambs (6.12 ± 0.35; $P < 0.01$).

The recommended dietary ratio for n-6:n-3 PUFA is given as smaller than 4.0, while the P:S ratio is advised to be greater than 0.4 (Wood *et al*., 2008). It has been shown that with a decrease in intramuscular fat (IMF) in the meat the ratio of P:S increases (Strasburg *et al.*, 2008; Webb & O'Neill, 2008). Therefore, having less fat stored in intramuscular fat (IMF) depot's (Epstein, 1960; Almeida, 2011a; Yousefi *et al.*, 2012) the meat of the Namaqua Afrikaner could be marketed as lean, with the possibility of having a more beneficial P:S ratio – a characteristic which, if marketed appropriately as the healthier choice, could be advantageous to the meat producer as present day health conscious consumers have a preference for lean red meat (Higgs, 2000; Webb & O'Neill, 2008; Yousefi *et al.*, 2012).

In previous years the Namaqua Afrikaner was farmed with on a large scale in South Africa, but at the moment this breed has fallen into commercial obscurity, despite the obvious advantages of being superiorly adapted to arid climates (Epstein, 1960). Part of this could be connected to the fact that abattoirs tend to downgrade fat tailed carcasses due to a lower lean yield although anecdotal information has it that if the tail is trimmed on a warm carcass, when chilled this trimming is not visible. On the subject of the meat quality and sensory attributes of the indigenous fat-tailed Namaqua Afrikaner, information in literature could not be found – a direct result of the previously presumed inferiority in meat yield and quality of indigenous breeds (FAO, 2003), as well as their traditionally lower financial importance, especially to consumers in developed countries (Tshabalala et al., 2003). At present most of the stock is owned by research institutions within South Africa (Hugo, 1966; ARC, 2010) and the breed is now listed on the *World Watch List – for domestic animal diversity* as "Endangered" (FAO, 2000). According to this list a species is endangered if the total number of (FAO, 2000):

- breeding ewes is higher than 100 but equal or less than 1000; or
- breeding males is higher than five but equal or less than 20; or
- the population is between 80 and 100 and increasing, while the percentage of females being bred to males of the same breed is higher than 80%; or
- the population is between 1000 and 1200 and decreasing, while the percentage of females being bred to males of the same breed is higher than 80%.

However, it is very difficult to determine the exact number of Namaqua Afrikaner in South Africa and Namibia as no reliable data exists on the size of the national flocks and the breeds that comprise said flocks. Most of the data available is linked to specific stud breeders and does not include information about the commercial breeders. The Namaqua Afrikaner has no registered breeding stud at present.

2.7 Dorper

During the 1930's the demand originated for a sheep breed, not only adapted to the harsh South African climate, but also able to compete with the meat quality of the meat breeds from Argentina, Australia and New Zealand (Campbell, 1980; as cited by De Waal & Combrinck, 2000; Nel 1993; Milne, 2000). The Dorper was such a composite breed, developed as a sheep breed that could compete on the international meat markets in terms of quality (De Waal & Combrinck, 2000; Milne, 2000).

The Great Depression of the 1930's had a marked impact on the global economy and in the South African market it resulted in an excess of meat and wool (Schoeman, 1980; as cited by De Waal & Combrinck, 2000; Nel, 1993; Milne, 2000). Exporting meat seemed to be the answer, but the fat-tailed (Ronderib- and Namaqua Afrikaner) and fat-rumped (Blackhead Persian) breeds then farmed with, did not compare favourably with mutton from countries such as Australia, New Zealand and Argentina (Nel 1993; Milne, 2000). The British consumer in particular found the eating quality of the meat of the fat-tailed sheep irreconcilable with their taste preferences (Nel 1993; Milne, 2000).

The Department of Agriculture of South Africa recognised the need to improve the quality of South African mutton and thus crossbreeding programs were undertaken in collaboration with local farmers (Ramsay *et al.,* 2001). The British mutton breed, Dorset Horn, was chosen as sire breed. It has a good carcass conformation, uniform fat distribution and a longer breeding season when compared to other British mutton breeds (Nel, 1993; Milne, 2000). The Blackhead Persian, originating from Somalia and the surrounding North African and Asia-minor areas, were chosen as dam breed (Campbell & Hofmeyer, 1972). In addition, the Blackhead Persian is a fat-rumped breed with superb resistance to extreme climate conditions and has a year-round lambing ability (Campbell & Hofmeyer, 1972).

The cross obtained from these two breeds resulted in the now world-renowned composite Dorper breed, established in 1946 (Nel, 1993; Milne, 2000). Standing at 24% of the National Small

Stock Improvement Scheme (NSIS) records, the Dorper is currently the principal commercially farmed meat breed farmed with in South Africa (Cloete & Olivier, 2010). Since the Dorper is the principal meat breed, it can be expected that the meat of the Dorper sheep will be tender and juicy on consumption (Milne, 2000; Ramsay *et al.,* 2001; Snowder & Duckett, 2003).

The Dorper is an early maturing breed and can be slaughtered at a younger chronological age than its later maturing counterparts (Webb and Casey, 1995; Cloete *et al.,* 2000; Milne, 2000; Cloete *et al.*, 2007). As a result of the excellent carcass traits and meat quality of the Dorper, Dorper rams are popular as terminal sire breed (Snowder & Duckett, 2003). A disadvantage, however, could be found in the possibility of the Dorper reaching maturity at an earlier chronological age. When slaughtered at lower live weights and a younger chronological age, the carcasses could be too small with a low dressing percentage. Dorper ewes have a good mothering ability and their fertility rate is in general higher than that of woollen breeds (Schoeman, 2000; Ramsay *et al.,* 2001). It has also been noted that the survival rate of Dorper lambs is overall high (Cloete *et al.,* 2000) and that they have a higher average daily gain (ADG) post weaning in comparison with wool breeds such as Merinos (Basson *et al*,. 1970).

This is a non-labour intensive breed, which is well adapted to the South African temperature conditions of cold winters and hot summers (Ramsay *et al.,* 2001; Snowder & Duckett, 2003), but regrettably do not fare as well in the African tropics (Schoeman, 2000). As a result of its versatility and adaptability the Dorper has become coveted in the global agriculture (Cloete *et al.,* 2000). At present the Dorper can be found in countries such as Israel (Elias *et al.,* 1985), Saudi Arabia, Zimbabwe, Zambia, Kenya, Mauritius and Malawi as well as the United States of America and Australia (Nel, 1993; Cloete *et al.,* 2000; Milne, 2000; Snowder & Duckett, 2003).

However, it is very important to take note of the findings by Snyman *et al.* (1996b). It was reported that while the monetary yield on Namaqua Afrikaner carcasses might be smaller than that of the commercial breeds (Dorper and Afrino) when sufficient grazing is available, the Namaqua Afrikaner outperform these breeds under severe drought conditions. In their study Snyman *et al.* (1996b) reported that the commercial breeds were provided with additional feed to supplement available pasture, thus raising farming (input) costs. However, it was not necessary to supplement the paddocks utilised by the Namaqua Afrikaner, and it still outperformed the latter breeds, highlighting the hardiness of the Namaqua Afrikaner and its ability to withstand nutritional strain (Snyman *et al.*, 1996b). Thus it can be postulated that although the Dorper was developed through selection to be adapted to the South African climate, it is not as well adapted as the Namaqua Afrikaner. In addition it can be argued that with climate changes favouring warmer weather patterns the Namaqua Afrikaner, resultant of its hardy nature, will be able to adjust more easily to changes in its environment.

2.8 South African Mutton Merino

The South African Mutton Merino (SAMM) is the main dual-purpose breed (6% of the NSIS records), farmed with for its meat and wool (Cloete & Olivier, 2010). The SAMM is a descendant of the German Merinos that were imported by the Elsenburg Agricultural College in 1932 (Neser *et al.,* 2000; Ramsay *et al*., 2001; SA Mutton Merino Society, 2013a). Through selection for a better body conformation and wool quality the breed underwent several changes and in 1971 it was recognised as a separate breed, with little resemblance to the original German Merino breed (Neser *et al.,* 2000; Ramsay *et al*., 2001; SA Mutton Merino Society, 2013a).

The SAMM is well adapted in semi-arid and high rainfall, sour grassveld regions (Ramsay *et al*., 2001). It is a late maturing breed and has the advantage of producing a carcass with less fat than the early maturing breeds when slaughtered at the same chronological age (Cloete *et al*., 2007; Cloete *et al*., 2012). The carcass of the SAMM has a good conformation and its meat is deemed as tender and of high quality (Neser *et al.,* 2000; Ramsay *et al*., 2001; SA Mutton Merino Society, 2013b). As the SAMM has the ability to easily convert feed into lean tissue, it is an optimum choice breed for intensive farming systems (SA Mutton Merino Society, 2013b).

The SAMM ewes also have a high fertility as well as high fecundity (multiple births) and are considered as having good mothering abilities (Ramsay *et al.,* 2001; SA Mutton Merino Society, 2013b).

Through utilising the diversity in genetic resources of South African sheep breeds, as investigated in this study, opportunities are created to meet the current and future trends in consumer demands, to improve food security, alleviate poverty as well creating a buffer against climate and other environmental changes' impact on agricultural production.

2.9 Crossbreeding

Crossbreeding refers to the mating of divergent breeds for commercial gain. Production gains in crossbreeding situations depend on non-additive gene action resulting in production gains above the average of the breeds used in the formation of the cross. This improvement in performance is termed hybrid vigour or heterosis (Kinghorn & Atkins, 1987) and is commonly related to interactions within loci (dominance) and interactions between loci (epistasis) (Swan & Kinghorn, 1992). Individual heterosis is usually maximised in the first cross between divergent populations (Leymaster, 2002). Heterosis is more likely to occur in lowly heritable fitness traits than in production traits with generally higher heritability estimates (as reviewed by Nitter, 1978 for ovine heterosis estimates and by Safari *et al*., 2005 for ovine heritability estimates). Heterosis in sheep amounts to 3-10% in lambs, and is usually associated with an improved lamb survival, early growth and resistance to common stressors (Fogarty, 2006). However, crossbred dams may also be used in terminal crossbreeding productions systems. Higher levels of heterosis are expected for ewe reproduction traits amounting to 10-40% for weight of lamb weaned per ewe mated (Fogarty, 2006). Additional advantages of crossbreeding systems in sheep involve feeder-breeder dimorphism (Roux, 1992). Sexual dimorphism for size in sheep, where the weight of the ram breed greatly exceeds that of the ewe breed, may thus contribute to commercial gains in sheep crossbred systems (Cloete *et al*., 2004). Crossbreeding may also allow the crossbred progeny of early-maturing and adapted Dorper ewes to be grown out to heavier slaughter weights compared to purebred progeny without being downgraded because of excessive fat cover (Cloete *et al*., 2007).

Crossbreeding between the SAMM and the Dorper in the present study followed on the previous study by Cloete *et al*. (2007). The latter study found that SAMM x Dorper progeny could be grown out to a marketing weight of >40 kg, while maintaining fat depths suitable for the best grades. The previous study was extended to study heterosis effects on lamb survival and early growth, as well as on reproduction traits of mature ewes for which a reciprocal crossbred design is needed. Data on offspring meat traits of purebred and crossbred lambs became available as a by-product of this study. Moreover, indigenous animals are often “upgraded” by crosses with “improved” commercial breeds to result in offspring with more desirable attributes for specific traits of economic importance (Piedrafita *et al*., 2010; Pannier *et al*., 2014). Against this background, Namaqua Afrikaner rams were crossed with Dorper ewes to research the potential benefits of such a cross. It was envisaged that the resultant crossbred progeny would have improved meat attributes, which is lacking in the Namaqua Afrikaner (Burger *et al*., 2013). Such a cross may also maintain an improved tolerance to stressors like tick infestation, for which the Namaqua Afrikaner proved to be superior to the commercial sheep breeds at Nortier (Cloete *et al*., 2013a). A cross between an indigenous breed (the Damara) and a commercial breed (the Dorper) similarly resulted in the formation of the Meatmaster breed in South Africa (Peters *et al*., 2010a).

2.9.1 Temperament

The innate character of certain sheep breeds (determined by genetic and permanent environmental effects as experienced in early life) has them more predisposed to the handling of stressful situations than others (Bates *et al.*, 1995). Burrow (1997) found that animals with a calmer temperament have a higher growth rate when compared to highly nervous or responsive animals. Domestication and selection for the improvement of production and economical viable traits have resulted in sheep with a more amicable temperament (Hansen *et al.*, 2001; Viérin & Bouissou, 2003; Jorgensen *et al.*, 2011; Dodd *et al.*, 2012). Hansen *et al*. (2001) found that the anti-predator (fight or flight) responses are stronger in light (weight) breeds which have not been altered by commercial selection for the improvement of meat quality. It can be argued that by being South Africa’s principle meat breed, the Dorper’s temperament has been improved through genetic selection done to enhance meat quality (Zohary *et al.,* 1998). Consequently it is postulated that the Dorper will have less severe responses to stressful stimulus (e.g. humans, abattoir environment). In contrast the Namaqua Afrikaner is an unselected breed, and according to anecdotal data, supported by preliminary results from Cloete *et al.* (2013b), more anxious and "flighty" when exposed to stressful stimuli.

2.10 Consumer perceptions and preferences

In their day to day living the food choices made by consumers is the result of preconceived ideas concerning food products (Smolin & Grosvenor, 2003; Grunert *et al.*, 2004; Troy & Kerry, 2010; Montossi *et al.*, 2013). These ideas are based on information obtained through the media as well advice from food manufacturers and health authorities (physicians, dieticians and other health care workers) (Smolin & Grosvenor, 2003; Font-i-Furnols & Guerrero, 2014). The consumption of meat, and specifically red meat, is further influenced by the consumer's standard of living (general financial position, family and health aspects and education level) together with the characteristics of the product itself (sensory properties, nutritional value, price, convenience) (Longdell, 1997; Jiménez-Colmenero *et al.*, 2001; Grunert, 2006).

It is very well known in the food industry that consumer want and demands are ever changing (Troy & Kerry, 2010; Montossi *et al.,* 2013) and are influenced by the consumer's willingness to purchase and pay for a desired product (Troy & Kerry, 2010). Willingness to purchase is influenced by the consumer's perception of the related product. In the meat sector, where consumer demands have changed decidedly over the last twenty years (Montossi *et al.,* 2013), this is particularly true (Troy & Kerry, 2010). While the global red meat industry used to be predominantly production driven, it has been evolving towards being driven by consumer satisfaction, thus meeting consumer demand (Issanchou, 1996; Troy & Kerry, 2010). According to the most recent studies product quality is becoming more and more important as a driver in consumer purchase-intent behaviour (Henchion *et al.*, 2014).

Apart from quality, several other concepts influence the purchasing intent of different segments of consumers (Montossi *et al*., 2013). Currently various consumers are voicing concerns with regard to the sustainability of intensive animal production, focussing on its possible impact on and contribution to climate change (Montossi *et al.*, 2013). In addition concerns regarding general production practices and animal welfare are also important to consumers (Verbeke & Viaene, 2000). Furthermore, aspects such as social and religious values, possible influence on health and place of origin are also considered as important in determining consumer preferences (Sañudo *et al.*, 1998a; Font-i-Furnols *et al*., 2011). Different studies have shown that consumers prefer locally-grown products, as they believe that these products would be of higher quality and also fresher. Additionally, buying local products inspire a feeling of patriotism with consumers as they are supporting their domestic economy (Font-i-Furnols *et al*., 2011; Font-i-Furnols & Guerrero, 2014). Furthermore, it could be argued that as local products are not transported over vast distances (i.e. not imported), a lower level of carbon emissions is associated with the production of said products (Montossi *et al.*, 2013).

2.10.1 Meat quality

By definition quality is “the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs” (ISO 8402; as cited by Becker, 2000). Luning and Marcelis (2009) continue to describe quality as being representative of the attributes of a product that will address both the physiological and/or psychological needs of a consumer through “meeting or exceeding customer and consumer expectations”. Molnár (1995) expands on this when stating that the safety, nutritional value, convenience and sensory properties of a product determine its quality. The term “meat quality” would thus imply that a meat product meets the consumers’ needs in terms of physical, nutritional (chemical) and sensory properties (Claasen, 2008) while simultaneously satisfying consumer expectations (Longdell, 1997).

According to Warriss (2000) two concepts can be used to define meat quality. The first is functional quality, which can be described as the desirable attributes of the product e.g. tenderness and flavour. Secondly, conformance quality refers to a product that will meet the expectations of the consumer precisely according to predefined specifications e.g. portion size (Warriss, 2000).

Darby and Karni (1973) divide the concept of quality into three classes i.e. search, experience and credence. These concepts can be extrapolated and applied to food and specifically meat quality (Grunert *et al.,* 2004). Search quality will refer to the appearance of the meat and can be evaluated before purchase, whereas an experience quality, for example taste, can only be evaluated on consumption and thus after purchase. Lastly, the credence quality of a product (e.g. nutritional value) can generally not be measured by the average consumer, who has to trust and rely on information provided, for example on packaging (Darby & Karni, 1973; Grunert *et al.,* 2004).

Additionally, to the different role players in the food production and supply chain the term “quality” has different meanings, which is also influenced by their cultural background and again by personal experiences (Becker, 2000; Warriss, 2000). Sañudo *et al.* (1998a) investigated the influence of different cultural backgrounds on consumer preferences. Assessments of the eating quality of meat from lambs originating in Spain and Britain were done by two different trained sensory panels – also from Spanish and British origin. Both panels came to the same conclusion: that the meat from the British lambs was stronger in odour and flavour whereas lambs from Spanish origin presented meat with a higher juiciness value. However, when these panels were asked for their choice of preference the British panel chose the meat from the British lambs and the Spanish panel the Spanish meat (Sañudo *et al.,* 1998a). These findings clearly demonstrate how cultural background (and possible habituation) and previous experiences could dictate consumer preferences (Warriss, 2000).

With the assistance of the intrinsic and extrinsic quality cues available, expectations of quality are formed according to previous experiences and these will influence and determine a consumer’s willingness to purchase a product in the future (Sañudo *et al.,* 1998b; Grunert *et al.,* 2004). Intrinsic and extrinsic cues are product information provided and utilised to make informed decisions about the expected quality (Steenkamp, 1990; Grunert *et al*., 2004; Henchion *et al*., 2014). The physical and technical characteristics i.e. colour, marbling, taste, tenderness, juiciness, cut etc. are classified as intrinsic quality cues, whereas extrinsic cues are: brand name; price; packaging; sell/use by dates; quality labels; place of origin; supplier and information regarding animal welfare (Henchion *et al.*, 2014).

To the (red) meat consumer the important features of meat quality are the appearance (colour, exudate and visible fat i.e. marbling) and the related technological characteristics (water holding capacity) of the meat as well as the palatability (texture, juiciness, flavour) thereof (Warriss, 2000). Appearance is a search quality and in fact the only attribute that can be utilised by a consumer to judge the quality of a product at point of purchase (Darby & Karni, 1973; Warriss, 2000; Grunert *et al.,* 2004). Being the first quality cue observed by the consumer, the appearance of the product is responsible for the first impression of the product on said consumer and is consequently contributing to the perceived commercial value of the product (Fortomaris *et al.*, 2006). For example: appearance cues such as visible exudate in the packaging will adversely affect the overall appearance of the product, while associating with negative results for the perceived juiciness of the product (Warriss, 2000).

In the mind of the consumer eating quality equals palatability, including texture (tenderness), juiciness and flavour, in this specific order (Warriss, 2000). In general, consumers in the developed countries prefer tender meat, whereas consumers in certain African countries prefer tougher (more chewy) meat (Warriss, 2000; Lawrie & Ledward, 2006b).

Attributable to the health implications related to consumption of red meat, consumers prefer lean meat, but at the same time excellent aroma and taste are expected when consuming meat (Warriss, 2000; Webb & O'Neill, 2008; Wood *et al.*, 2008). Grunert *et al.* (2004) showed that consumers place a high value on the taste, tenderness, juiciness, freshness, leanness and nutritional value of a meat product. However, a fact that is disregarded by many consumers is the relationship that exists between the fat content of meat and the eating quality thereof (Warriss, 2000; Grunert *et al.,* 2004; Yousefi *et al.*, 2012). The same study (Grunert *et al.,* 2004) indicated that the average consumer believes that any marbling present subtracts from the organoleptic properties of the meat and consumers do not realise that a certain degree of intramuscular fat or marbling is necessary to obtain an ideal flavour profile.

In the South African meat industry an A2 lamb would be regarded as having an optimum level of fat on its carcass (Van Heerden *et al.,* 2007); with subcutaneous fat depth of between 1-4 mm fat, measured between the third and fourth lumbar vertebrae; 25 mm from the midline of the spine (GG 14060, 1992, R1748). In addition, research has shown that intra-muscular fat has a decreasing effect on the toughness of meat and improve the juiciness thereof (Warriss, 2000; Grunert *et al*., 2004). Juiciness also influences the perception of tenderness – sensory panels have assessed juicy samples as more tender and less juicy samples as less tender, where the results of tenderness were similar when instrumental shear force analyses were done (Warriss, 2000).

2.11 Nutritional quality of meat

Although classified as a credence quality, the nutritional quality of meat is an important characteristic, highly valued by all consumers (Font-i-Furnols & Guerrero, 2014). Consumers' impression of red meat used to be positive and meat were classified as nutritious and healthy (Higgs, 2000; Valsta *et al.*, 2005; Strasburg *et al.*, 2008). Historically, the consumption of meat has also been associated with prosperity and wealth and thus the consumption of meat has increased with higher incomes (Higgs, 2000; Strasburg *et al.*, 2008; Henchion *et al.*, 2014).

2.11.1 The health/diet interface

However, time (era) and research can also influence consumer perception of quality and thus consumer demand (Warriss, 2000). Since the 1980's the nutritional image of meat has changed significantly and consumption of red meat has declined markedly (Higgs, 2000). Several studies have linked high dietary consumption of red meat, and in particular the saturated fatty acid (SFA) content thereof, to the occurrence of colorectal cancer (Larsson *et al.*, 2005; Sinha *et al.*, 2005; Cross *et al.*, 2007) and cardiovascular diseases (CVD) (Keleman *et al.*, 2005; Steffen *et al.*, 2005; Azadbakht & Esmaillzadeh, 2008) as well as other non-communicable diseases associated with a western lifestyle e.g. hypertension, obesity and metabolic syndrome (Higgs, 2000; Jiménez-Colmenero *et al.*, 2001; Wood *et al.*, 2003; Biesalski, 2005; McNeill & Van Elswyk, 2012).

Meat is considered as a key contributor of fat to the human diet (Wood *et al.,* 2003), which brought about dietary advice being focused on the association between the consumption of SFA found in meat and the non-communicable diseases mentioned – advising consumers to reduce their intake of red meat (Binnie *et al.*, 2014). As a result consumer perceptions have been negatively inclined towards red meat and the fat content thereof, even though meat contains not only SFAs but a combination of saturated and unsaturated fatty acids (Reiser & Shorland, 1990, as cited by Webb *et al.*, 1994; Biesalski, 2005). Owing to the association between the SFA and the detrimental effects thereof on human health, consumers nowadays prefer leaner meat of younger animals (Warriss, 2000). Nevertheless, it must be noted though that a large section of previous research findings (Keleman *et al.*, 2005; Larsson *et al.*, 2005; Steffen *et al.*, 2005; Cross *et al.*, 2007; Azadbakht & Esmaillzadeh, 2008) did not distinguish between processed meat products and fresh (red) meat; the former is known to contain more (added) fat (McAfee *et al.*, 2010). Recent studies have highlighted the importance of differentiating between processed (bacon, sausages, salami) and unprocessed (beef, veal, lamb) red meat (Binnie *et al.*, 2014) as no correlation between coronary heart disease (CHD) and the consumption of unprocessed red meat, within recommended dietary amounts, were found (McAfee *et al.*, 2010; Micha *et al.*, 2010; McNeill & Van Elswyk, 2012; Kappeler *et al.*, 2013; Rohrmann *et al.*, 2013; Binnie *et al.*, 2014).

Meat has a vast array of nutritional benefits, containing several essential nutrients key to a healthy lifestyle (Biesalski, 2005; Elango *et al.*, 2012; Binnie *et al.*, 2014), a fact which are often disregarded (Biesalski, 2005). It is considered a nutrient dense (total amount of nutrients per kilocalorie) source of minerals: iron; zinc; selenium; potassium; vitamins A and B (thiamine, riboflavin, B12) as well as essential amino acids (Warriss, 2000; Biesalski, 2005; Wyness *et al.*, 2011; Binnie *et al.*, 2014). As part of the diet, protein has a satiety inducing effect during consumption, and as a result a beneficial effect on lean muscle tissue in the human body (Higgs, 2000; McAfee *et al*., 2010). It is proposed that the satisfying effect induced by protein reduces the quantity of fats and carbohydrates consumed, thus reducing fat deposition to an extent. One of the most important benefits of meat consumption is meat being regarded as an important source of bioavailable iron, as well as enhancing the absorption of non-haem iron from plant sources (Cook & Monsen, 1976; Higgs, 2000; Warriss, 2000; Lawrie & Ledward, 2006a; McAfee *et al.*, 2010). According to Rogowski (1980) meat is considered the food source containing the highest amount of bioavailable iron as consumed by humans. Iron in meat (haem iron) is absorbed between three and five times more effectively by the human body than iron of plant origin (non-haem) (Cook & Monsen, 1976).

Growth in meat consumption per capita has reached a point of saturation in developed countries, with one of the reasons being the increasing health and dietary awareness of consumers (Henchion *et al.*, 2014). As part of finding strategies to improve dietary patterns, particularly in developed countries where gluttonous consumption are still prevalent but at the same time where consumers are still undernourished, consumption of nutrient dense foods such as lean red meat are being highlighted (Binnie *et al.*, 2014). Similarly, in developing countries all meat types can be considered as possible solutions to reducing malnutrition, while at the same time increasing food security (McNeill & Van Elswyk, 2012).

The chemical composition of food products is indicative of the nutritional value of the product (Strasburg *et al.,* 2008). In the case of sheep meat (lamb/mutton) the chemical composition would indicate a nutrient dense food substance, containing a wide range of different nutrients, which is also bioavailable to the human body (Rogowski, 1980; Strasburg *et al.,* 2008). Meat contains on average 70% moisture, 18-23% protein, 5% fat and 1-1.2% ash (Table 2.1) (Strasburg *et al.,* 2008).

Table 2.1 Chemical composition of lamb meat (Strasburg *et al.,* 2008)

Nutrient	**Percentage by weight of edible portion**
Moisture (g)	73.42
Protein (g)	20.29
Fat (g)	5.25
Ash (g)	1.06

Source: Compiled from U.S Department of Agriculture, Agricultural Research Service (2005). *Composition of Foods Raw, processed, Prepared.* USDA National Nutrient Database for Standard Reference, Release 18. Nutrient Date Laboratory Home Page (http://www.nal.usda.gov.fnic/foodcomp/) (Strasburg *et al.,* 2008).

Furthermore, it has to be borne in mind that the abovementioned results (Table 2.1) was determined by die United States Department of Agriculture and that it would certainly differ, albeit not very much, for South African sheep (Table 2.2) (Van Heerden *et al.,* 2007; Schönfeldt *et al.,* 2011).

Table 2.2 Chemical composition of South African lamb (A2) and mutton (C2) per 100g edible portion.

	Raw		**Cooked**	
Nutrient	**A2 Lamb**[1]	**C2 Mutton**[2]	**A2 Lamb**[1]	**C2 Mutton**[2]
Moisture (g)	71.5	73.8	65.4	64.6
Protein (g)	18.3	20.5	25.1	26.8
Fat (g)	9.01	8.98	8.44	11.6
Ash (g)	2.88	1.19	1.07	1.16

Source: Adapted from [1]Schönfeldt *et al.* (2011) and [2]Van Heerden *et al.* (2007).

However, these values are not fixed as different factors have an influence on the final results. These factors include breed, sex, age, diet and plane of nutrition, geographical location and activity level of the animal. Also, the specific cut that is analysed and post-mortem handling of the cut will have a significant influence on the results of the analysis (Sañudo *et al.,* 1998b; Lawrie & Ledward, 2006a, Strasburg *et al.,* 2008).

2.12 Carcass yield as a meat quality attribute

As with everything else in life, meat production also revolves around profit. Being able to provide the consumer with a retail cut carrying a higher meat to bone ratio will not only indicate a superior quality of meat to the consumer (Warriss, 2000). It will also be beneficial to the farmer, resulting in elevated profits as a greater meat: bone ratio equates to a greater well rounded carcass conformation which is more desirable (Kirton & Pickering, 1967). In the South African classification system this is accounted for by the classification of lamb/mutton carcasses into different conformation classes (Very flat = 1; Flat = 2; Medium = 3; Round = 4; Very round = 5) (GG 14060, 1992, R1748), however, producers (farmers) are mostly compensated for age and the degree of fatness.

2.12.1 Prediction of carcass composition of bone: fat: muscle ratio

It is important that the correct classification method is used to determine bone: fat: muscle ratio in a sheep carcass (Hedrick, 1983). It is also necessary to keep in mind how difficult and costly the method being used is as well as how accurate it is. Furthermore when carcasses of different breeds are compared it is important to establish the consistency of the method if it is used in any equation that would predict the bone: fat: muscle ratio of the carcass (Hedrick, 1983).

In the meat industry and in research the three-rib cut (9-10-11th rib) method is generally used to determine the bone: fat: muscle ratio of a sheep carcass (Hankins *et al*., 1943; Crouse & Dikeman, 1976; Hedrick, 1983). This method is regarded as precise and an excellent predictor of carcass yield. Research has indicated the existence of a positive relationship between the bone: fat: muscle ratio as determined with the three-rib cut and the bone: fat: muscle ratio of an entire carcass (Hankins *et al.,* 1943).

Contrarily, in the case of the Namaqua Afrikaner sheep breed, these statements might not be entirely accurate. As it is well known that the Namaqua Afrikaner stores surplus energy and fat in a fat-tail, rather than a thick subcutaneous fat layer (Epstein, 1960), it could be argued that the three-rib cut method will not be the optimal method to determine carcass yield of the Namaqua Afrikaner. Therefore, in the case of this study, it was decided to do complete deboning of the carcasses (meat, bone, fat) and determine carcass yield per cut as such.

2.12.2 The process of growth and maturity in relation to meat production and quality

The growth and development of animals can be seen as the basis of meat production, whereas the quality of the meat being produced is influenced by the quantity of lean meat as well as the quantity and location of fat in the carcass (Mahgoub & Lu, 1998; Sen *et al.,* 2004).

The single most important aspect of development and endurance, of any animal, is to be able to find adequate amounts of nutritious food (Elton, 1927). During the growth period of the animal different processes occur simultaneously (Hammond, 1940; Beitz, 1985; Warriss, 2000). The first is growth itself, which can be defined as an increase in total body cell mass or total body weight until the animal has reached its mature size. If presented on a graph, the growth pattern of the animal will take the shape of a sigmoidal curve (Fig. 2.2). At first the growth rate (increase in actual weight) is slow, but will continue to accelerate until a maximum rate of gaining weight is reached. This maximum point is typically reached at approximately 30% of the animal's mature weight – coinciding with reaching puberty. Thereafter, as the animal ages and available space for tissue growth decreases, the rate of gaining weight slows down (Hammond, 1940; Beitz, 1985; Warriss, 2000).

As growth is fastest at the maximum point of growth it is also most efficient because the proportion of the total energy available to the animal that is used for maintenance of its body is relatively low. At any time, growth is determined by the balance between accelerating and retarding forces. An example of an accelerating force is the increase in the weight of cells making up the body. Examples of retarding forces are the decrease in available space for a tissue to grow, or lack of nutrients. The maximum point of growth is where the two forces balance. This occurs at puberty (Warriss, 2000).

The second process taking place in unison with growth is development, which is regarded as the differentiation of the bodily cells (Beitz, 1985; Warriss, 2000) or as described by Arbele *et al* (2001) a gradual progression towards complexity. Through the differentiation of body cells, the various tissues, organs and limbs are able to grow at the distinctly different rates; compulsory for optimum functioning. This way the body conformation and size will accordingly change in different stretches and ratios as the animal continue to grow until maturity is reached (Hammond, 1940; Beitz, 1985; Warriss, 2000; Irshad *et al.*, 2012).

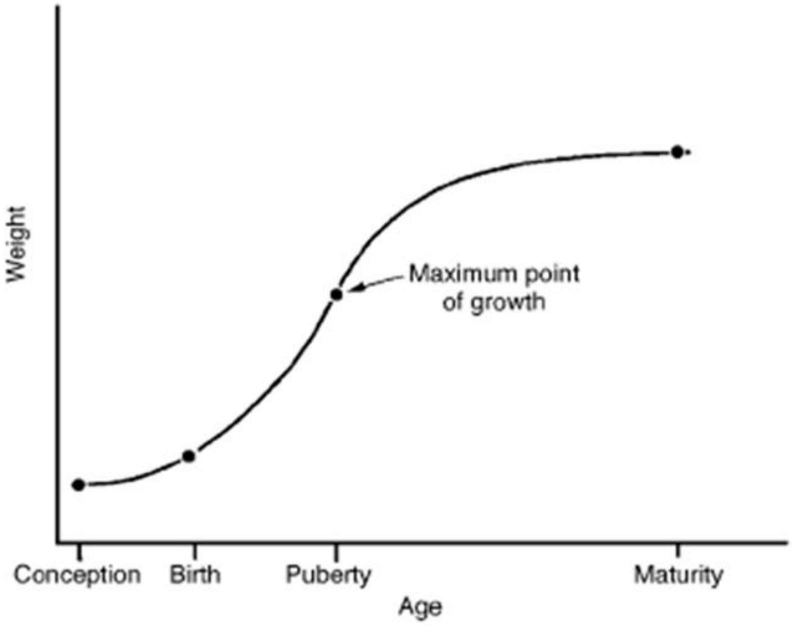
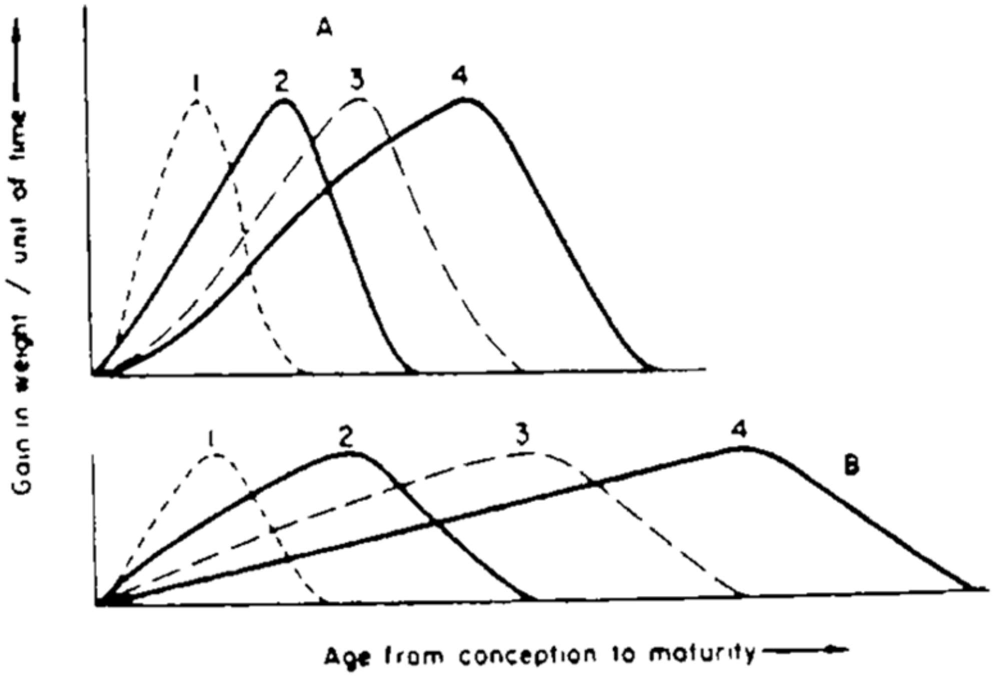


Figure 2.2 Presentation of the relationship between the age of an animal and its weight (Warriss, 2000).

Four main stages of development exist, each represented by a numbered curve on the graph (Fig. 2.3) (Pállson, 1955). Lawrie and Ledward (2006a) broadly summarise these stages in chronological order as: central nervous system; bone; muscle and adipose tissues. The rate at which maturity of the different tissues, organs and limbs are reached is consistent to the order of importance thereof for the survival of the animal (Fig. 2.3) (Pállson, 1955; Berg & Butterfield, 1975; Warriss, 2000; Lawrie & Ledward, 2006a). Furthermore, all of these curves or development cycles start together at time zero (conception) and continue simultaneously until maturity is reached; even though the timespan of each cycle is longer and the tempo is slower than the cycle before (Pállson, 1955; Berg & Butterfield, 1975; Butterfield, 1988a; Warriss, 2000).

When observing young (meat producing) animals after birth it can be noted that their heads are relatively large in comparison to body size (Berg & Butterfield, 1975; Warriss, 2000). This phenomenon can be attributed to the fact that the development of the brain (central nervous system) takes precedence, and thus the head will develop faster and mature at an earlier chronological age than any other part of the body (Fig. 2.3) (Pállson, 1955; Berg & Butterfield, 1975; Warriss, 2000; Lawrie & Ledward, 2006a). A primary growth surge will start at the head of the animal and continue downwards through the trunk towards the loin (Hammond, 1940). Following this, another growth surge will start at the limbs (extremities) and continue upwards, also towards the loin. These growth surges will come together between the last rib and the loin, which will be the final part of the body to develop and mature (Hammond, 1940).



Curves	1	2	3	4
	Head	Neck	Thorax	Loin
	Brain	Bone	Muscle	Femur
	Cannon	Tibia-fibular	Femur	Pelvis
	Kidney fat	Intermuscular fat	Subcutaneous fat	Intramuscular fat

(Courtesy the late Dr H. Pállson.)

Figure 2.3 Presentation of the relationship between the age of an animal and its weight – curve A representing a high plane of nutrition or early maturing animals and curve B a low plane of nutrition of late maturing animals (Pállson, 1955).

Following the central nervous system is skeletal growth (Pállson, 1955; Berg & Butterfield, 1975; Warriss, 2000; Lawrie & Ledward, 2006a). At the time of birth the percentage of bone in the body will be higher than at any other time during the entire lifespan of the animal (Berg & Butterfield, 1968). Percentage bone will continue to decrease as the animal continues to grow and increase in weight (Warriss, 2000). The final length of the bones will eventually define the size of the individual muscles to develop around these bones (Hammond, 1961). By implication this also defines the quantity of edible meat obtainable from such an animal's carcass upon slaughtering (Berg & Butterfield, 1968).

Muscle development follows the skeletal development (Pállson, 1955; Berg & Butterfield, 1975; Warriss, 2000; Lawrie & Ledward, 2006a). As the animal's growth and body development continues the percentage of bone in the body will decrease and the percentage of muscle will increase. Between birth and maturity the muscles are the tissue with the highest growth rate (Berg & Butterfield, 1968). Muscles that will be developing first would be those in the limbs, essential when the animal is foraging for food as well as the jaw muscles, required for the mastication of plant material (Berg & Butterfield, 1975). Also, the proper development and functioning of the limbs are a necessity in the animal's survival when threatened by predators (Pállson, 1955; Berg & Butterfield, 1975).

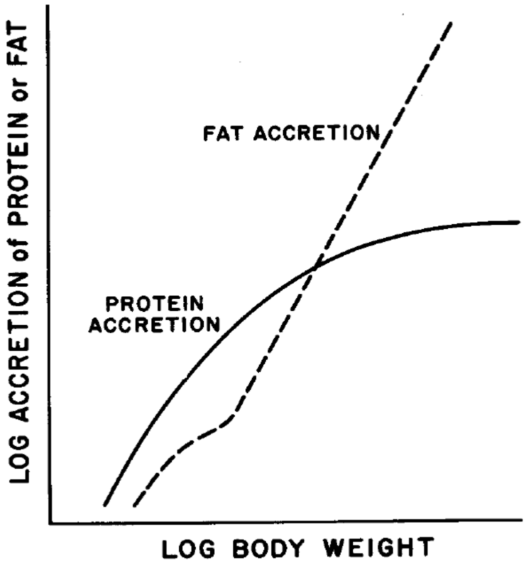


Figure 2.4 A presentation of the log plot of fat and protein accretion in meat animals (Bergen, 1974).

At the time of birth the percentage of fat tissue in the body is the lowest and it is also the last tissue to reach maturity (Berg & Butterfield, 1968). The percentage of muscle in the body will start to decrease after maturity has been reached and the percentage of fat will begin to increase (Fig. 2.3 & 2.4) (Pállson, 1955; Berg & Butterfield, 1968; Bergen, 1974; Butterfield, 1988a; Warriss, 2000; Lawrie & Ledward, 2006a). Different fat depots will mature during different phases of life (Beitz, 1985; Warriss, 2000). First the kidney fat (perinephric) matures, which is followed by the intermuscular fat. Thereafter subcutaneous fat, utilised for insulation, is deposited and finally the intramuscular fat deposits are formed (Fig. 2.3) (Pállson, 1955; Beitz, 1985; Warriss, 2000; Lawrie & Ledward, 2006a).

Different factors, including breed, age, sex, the diet and plane of nutrition, geographic location and activity level of the animal, will influence the growth rate as well as the quantity of muscle (protein) and fat a meat animal will develop and deposit (Lawrie & Ledward, 2006a, Strasburg *et al.,* 2008).

2.12.2.1 Chronological and physiological age

The differences in time taken to mature do not only have a biological impact on the animal's development, there are also economic consequences involved with the time taken to reach maturity (Warriss, 2000). Within species differences can be observed as animals from different breeds will grow and develop at different rates, and will therefore not reach physiological maturity at the same chronological age (Warriss, 2000; Lawrie & Ledward, 2006a; Irshad *et al.*, 2012).

For an early maturing breed the entire development cycle will occur and reach conclusion within a shorter time span than for a late maturing breed (Fig. 2.3) (Pállson, 1955; Lawrie & Ledward, 2006a). Two lambs, born on the same day (same chronological age) and reared under similar conditions will differ physiologically if one were of an early maturing and the other of a late(r) maturing breed. From the third curve on the graph (Fig. 2.3) it is clear that by the time muscle development of the early maturing lamb peaks, bone development of the late maturing lamb has just peaked and that its muscle development is still in an early phase. By the time the muscle development of the late maturing lamb has peaked, the muscles of the early maturing lamb have been fully developed and it has already reached the fattening phase. Hence, it can be deduced that at any chronological age, until physiological maturity is reached by both breeds, the muscle to bone ratio of an early maturing breed will be higher than that of a late(r) maturing breed (Pállson, 1955; Lawrie & Ledward, 2006a). The commercial impact thereof lies in the fact that the early maturing breed can be slaughtered at a younger chronological age than its late(r) maturing counterpart since its physiological development and more specifically its muscle development has been completed (Warriss, 2000; Lawrie & Ledward, 2006a; Cloete *et al.*, 2007).

Beyond a certain point of development gaining fat will be continuous and will thus become a larger part of the percentage weight of the animal (Fig. 2.4) (Bergen, 1974). To be able to obtain a carcass having a desirable percentage of fat (A2 lamb, SCF depth of 1-4 mm, measured between the third and fourth lumbar vertebrae; 25 mm from the midline of the spine) (GG 14060, 1992, R1748); reaching the point where fat accumulation become continuous should be delayed as far as possible (Bergen, 1974; Van Heerden *et al.,* 2007).

For example, being early maturing, Dorpers will start depositing fat at an earlier chronological age, which could result in an excessive gain of subcutaneous fat and suboptimum (too light) carcasses being produced (Cloete *et al.*, 2007). Webb and Casey (1995) established that the subcutaneous fat layer of Dorper wethers were significantly thicker than that of SA Mutton Merino wethers when compared at the same chronological age. Thus, to prevent the carcasses becoming undesirably fat, Dorper lambs can be slaughtered at a lower live weight of approximately 32-35 kg (Cloete *et al.*, 2007) instead of the commercial slaughter weight of approximately 40 kg applicable to other South African sheep breeds (Hoffman *et al*., 2003). However, this could lead to carcasses being too light, with smaller wholesale cuts.

Consequently it is expected that if lambs from early and late maturing breeds of the same chronological age are slaughtered at the same time, the carcass of the late maturing breed will contain a higher percentage of lean meat and overall less fat (Pállson, 1955; Warriss, 2000; Lawrie & Ledward, 2006a).

2.12.2.2 Plane of nutrition and nutritional stress

The plane of nutrition on which the animal is reared, will have a similar influence on growth and development as being early and late maturing have on the meat and other tissues of domestic animals (Fig. 2.3) (Pállson, 1955; Warriss, 2000; Lawrie & Ledward, 2006a). The development of animals on a high plane of nutrition will follow curve A, similar to early maturing, and that of animals on a low plane of nutrition will follow curve B, similarly to late maturing (Fig. 2.3) (Pállson, 1955; Warriss, 2000; Lawrie & Ledward, 2006a).

Currently global warming is another variable that needs attention with regard to the availability of grazing (Hoffmann, 2010). Not only will higher temperatures and lower rainfall reduce the yield and acreage of grazing land, but certain aspects of competition between plants species will also be affected (Ben Salem *et al*., 2011). Estimations indicate that as a result of global warming the growing seasons of plant species in many regions will become shorter, further influencing the availability and quality of grazing and thus the plane of nutrition for extensively raised livestock (Ben Salem *et al*., 2011). As a result of the higher levels of CO_2 (refer to section: 2.3 Climate change and global warming) an increase in the occurrence of woody plants (e.g. fodder shrubs) will occur, dominating over herbaceous plants (Reynolds *et al*., 2003; Peters *et al.,* 2010b).

The nutritional value of the vegetation consumed but livestock could also be affected by global warming. Formation of lignified plant tissues and secondary compounds such as tannins will negatively impact digestion in the rumen (McSweeney *et al*., 2001; Makkar, 2003; Ben Salem *et al*., 2011). Dietary proteins, mineral and other compounds including cellulose, hemicellulose and pectin bind with tannins to form insoluble complexes, resulting in the unavailability for absorption by the micro-flora in the rumen (McSweeney *et al*., 2001). If the nutritional composition of the vegetation ingested by the animals is negatively affected, it will result in an undesirable effect on the quality of the meat as well, since the plane of nutrition is low and the growth will be following curve B in Fig. 2.3 (Pállson, 1955; McSweeney *et al*., 2001; Lawrie & Ledward, 2006a; Ben Salem *et al*., 2011).

Differences in the diet selection of different sheep breeds can be expected (Blench 1999; Brand, 2000). Less-selective grazers should be able to accommodate for the shrub encroachment caused by global warming and still be able to obtain high-quality nutrients from available plant species (Hoffmann, 2010). According to Brand (2000), Dorper sheep are less-selective than Merino-type breeds and would graze on a larger variety and quality (if necessary) of plant species. The grazing range of the Dorper is also more extensive than that of the Merino-types in drier times, but when adequate feed is available Merinos would walk further to graze on plants of choice (Brand, 2000). Brand (2000) and Du Toit (1998) indicated that the Dorper prefer undergrowth and Karoo shrubbery, whereas the Merino prefers grass. Differences in plane of nutrition and thus differences in the actual diet influence the quality of the meat produced (Pállson, 1955; Warriss, 2000; Lawrie & Ledward, 2006a; Chedid *et al.*, 2014).

2.12.2.3 The effect of heat stress on animals and meat quality

Another direct effect of climate change on animals will be in the form of heat stress suffered as a result of the elevated temperatures (Marai *et al.,* 2007; Ben Salem *et al*., 2011; Chedid *et al*., 2014). Although Warner *et al*. (2002) did not find any lasting effects on lamb meat quality due to dehydration, several biological processes in the animal will be affected by heat stress. This includes growth and reproduction performances, and could eventually result in deterioration in the quantity and quality of meat obtained from such an animal (Marai *et al.,* 2007; Ben Salem *et al*., 2011; Chedid *et al.*, 2014).

Animals are generally adapted to a specific thermo-neutral temperature range where an average body temperature is maintained and growth and reproduction can take place (Marai *et al.,* 2007). If temperatures are elevated above the neutral range, animals will suffer from heat induced stress, which will result in a suppressed appetite and lower feed intake (Marai *et al.,* 2007; Hoffmann, 2010; Chedid *et al.*, 2014). As a result of the lower feed (nutritional value) intake, growth is effected as the anabolic activities in the tissues decreases and at the same time tissue catabolism increases (Habeeb *et al.,* 1992; Marai & Habeeb, 1998; Marai *et al.,* 2007; Hoffmann, 2010). When animals are exposed to high temperatures the peripheral thermal receptors are stimulated and nerve impulses are sent to the hypothalamus, where the appetite centres is situated, suppressing the animal's desire for food (Marai *et al.,* 2007). By ingesting less food, fewer substrates become available for enzyme activities and hormone synthesis (Habeeb *et al.,* 1992; Marai & Habeeb, 1998). As the metabolic activities slow down, metabolic heat production and thus body heat is diminished, but the metabolism and utilisation of protein is also reduced (Habeeb *et al.,* 1992). This decrease in available metabolic energy needed for the maintenance and repair of existing tissues and production of new tissues results in a slow-down in growth and possible deterioration of meat quality. As the synthesis of new proteins do not occur fast enough to counteract tissue catabolism, a negative nitrogen balance is created as a result of high levels of proteolytic hormones such as glucocorticoid hormones (Habeeb *et al.,* 1992; Marai & Habeeb, 1998). High levels of lipolytic hormones and a decrease in insulin (which is among others responsible for protein synthesis through the control of amino acid uptake) could also lead to the catabolism of tissues (Habeeb *et al.,* 1992).

Furthermore, heat stress causes sheep to lose water through sweating (minor) and panting (major) as the sheep attempts to keep their body temperature normal (Marai *et al.,* 2007). The animals are more susceptible to dehydration as loss of water is continuous whereas water intake is intermittent (Hoffmann, 2010). Studies by Jacob *et al.* (2006) suggest that depriving the animal of water will increase the dry matter concentration in the muscles as well as the osmolality thereof. Results also indicated that the individual muscle fibres shrink as a result of dehydration (Jacob *et al.,* 2006).

2.13 Summary

At the moment global agricultural production are faced with an urgency to increase and optimise food production as a result of the rapid population growth and urbanisation – a situation further exacerbated by global warming. In South Africa a similar situation exists, with the largest part of farmland situated in arid and semi-arid regions. In order to optimise mutton/lamb meat production, while keeping inputs costs the same, the possibilities of farming with indigenous sheep breeds are being investigated. While indigenous breeds are adapted to the harsh South African climate and could be regarded as non-labour intensive, very little information are available on the meat quality of such breeds. Since red meat consumers consider the eating quality of meat as the most important characteristic, while expecting a product beneficial to health, it is necessary to investigate these properties of the meat to be able to ensure that quality is maintained and consumer expectations are met.

At present limited very information regarding the meat quality attributes and carcass yield of the Namaqua Afrikaner is available. Therefore the comprehensive objective of this study is to investigate the meat quality of the indigenous Namaqua Afrikaner sheep and to contribute scientific results which can be used as baseline data in future research on the Namaqua Afrikaner and other indigenous, fat-tailed breeds. This will be done through the investigation of the carcass yield, physical and chemical properties, and the sensory profile of the meat and compared to the same characteristics of the commercial breeds (Dorper and SAMM) currently farmed for meat production.

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CHAPTER 3

Carcass composition of Namaqua Afrikaner, Dorper and SA Mutton Merino ram lambs reared under extensive conditions[1]

Abstract

This study evaluated the differences in the muscle-fat-bone yield of Namaqua Afrikaner, Dorper and SA Mutton Merino (SAMM) ram lambs. The breeds constituted an indigenous, hardy and late maturing, fat-tailed breed (Namaqua Afrikaner), an early maturing, commercial meat breed (Dorper) and a late maturing, commercial dual-purpose breed (SAMM). Lambs were slaughtered at 35 (± 8) days post weaning. Carcasses were cooled for 24 h, separated into retail cuts (leg, loin, rib, and shoulder), weighed and deboned. Meat and fat were separated after deboning and weighed to calculate the muscle-fat-bone yield per cut. Least-square means were computed for the respective breeds, using slaughter age as covariate. Results for percentage meat indicate that, with exception of the rib, retail cuts from the Namaqua Afrikaner breed contained a lower percentage of meat than either Dorper or SAMM breeds, particularly in the valuable loin and leg cuts. The percentage fat in retail cuts did not differ between breeds for any of the cuts. In comparison with both Dorper and SAMM, Namaqua Afrikaner contained a higher percentage bone in all cuts. Dorper and SAMM carcasses did not differ in terms of the percentage of bone, fat or muscle for any of the retail cuts. The lower meat yield, particularly in the more expensive loin and leg of the Namaqua Afrikaner, when compared to the commercial meat breed (Dorper) could make the former less preferred for meat production. However, the Namaqua Afrikaner compared more favourably with the dual-purpose SAMM. Differences in carcass composition could be attributed to the fact that the Namaqua Afrikaner is an unimproved and late maturing sheep breed.

Keywords: Early maturing, indigenous, late maturing, muscle-fat-bone yield, retail cuts, sheep

3.1 Introduction

The largest part of South Africa is located in either an arid or semi-arid region, limiting possible agricultural production to pastoral use (Cloete & Olivier, 2010). Due to global weather changes tending towards a drier climate in the south-western parts of South Africa, natural food resources for livestock are forecast to diminish (Turpie *et al.*, 2002). This changing scenario is expected to result in challenges to small stock farming as far as adaptation of animals and the sustainability of farming is concerned.

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During 2011, South African sheep meat (lamb and mutton) consumption was estimated at 149 000 tons. Only 140 000 tons were produced within South Africa, clearly indicating a demand for increased and optimised sheep meat production in South Africa (DAFF, 2012; FAO, 2012). Thus, it is evident that the local animal genetic resources should be harnessed optimally to ensure sustainable sheep meat production under variable and often adverse conditions.

Owing to the association between the saturated fatty acids (SFA) found in red meat and the detrimental effects of SFA on human health, consumers prefer leaner meat of younger animals (Warriss, 2000). Coronary heart disease (CHD) and certain cancers, such as colon cancer, have been linked to a high dietary intake of SFA (Higgs, 2000; Wood *et al.*, 2003). While meat contains a combination of saturated and unsaturated fatty acids, consumers have made the assumption that all the fatty acids in meat are saturated, deeming red meat as unhealthy and creating a negative association with red meat consumption (Reiser & Shorland, 1990, as reviewed by Webb *et al.*, 1994).

However, the nutritional benefits of meat is often overlooked (Biesalski, 2005). Meat is considered as a nutrient dense source of micronutrients including selenium, vitamins A, B12 (only found in animal products) and folic acid, as well as essential amino acids and proteins with high biological value (Warriss, 2000; Biesalski, 2005). Another nutritional attribute of red meat is that it is regarded as one of the best food sources of bioavailable iron, as consumed by humans (Warriss, 2000; Lawrie & Ledward, 2006). Meat consumption should thus be balanced as part of a diverse diet, keeping cuts lean with excess fat trimmed (Higgs, 2000; Biesalski 2005).

Three sheep breeds, representing a wide spectrum of the local ovine genetic resource, were studied for their lean meat production potential. These included the Namaqua Afrikaner, an indigenous, hardy and late maturing, fat-tailed breed, the Dorper, an early maturing, commercial meat breed and the late maturing, commercial dual-purpose South African Mutton Merino (SAMM).

The Namaqua Afrikaner is well known for its ability to survive the harsh South African climate (Epstein, 1960). The ancestors of the Namaqua Afrikaner can be traced back to the fat-tailed sheep owned by the northern Namaqua Khoi people and thus it is regarded as a national heritage. The Namaqua Afrikaner has a slender body with long legs, well adapted for walking vast distances in search of food and water. Body fat is mostly accumulated in the fat-tail and fat deposits on the loin are minor (Epstein, 1960). Fat-tailed sheep are well known for their ability to survive in harsh environments. Instead of the subcutaneous layer of fat used for insulation, the adaptive response is to store surplus fat in the tail, with minor fat deposits in the rest of the body. The fat-tail acts as a depot for reserve fat in times of abundance and is utilised when food and water are scarce (Epstein, 1960).

The Dorper is the largest commercially farmed meat breed in South Africa and the second largest sheep breed overall, contributing 24% of the weaning weight records to the National Small Stock Improvement Scheme (NSIS) (Cloete & Olivier, 2010). Dorpers are early maturing sheep, showing excellent carcass characteristics, as well as adaptation to adverse environments (Webb & Casey, 1995; Brand, 2000).

The SAMM is the main dual-purpose breed (6% of the NSIS records), farmed for meat and wool (Cloete & Olivier, 2010). The SAMM has a strong, large body frame with good meat quality attributes e.g. tender meat with a reduced back-fat depth (Cloete *et al.*, 2007). It is a late maturing breed and thus meat of the SAMM should have less fat than that of the Dorper if slaughtered at the same chronological age (Van der Westhuizen, 2010)

The main objective of the study was to assess the indigenous, unimproved Namaqua Afrikaner against the two commercial breeds (Dorper and SAMM) in terms of the quantity of meat yielded.

3.2 Materials and methods

Twenty nine male lambs of the Namaqua Afrikaner (n = 13), Dorper (n = 10) and SAMM (n = 6) breeds were randomly selected from the flock on the Nortier Experimental farm (32°02'S and 18°20'E), situated in the West Coast Strandveld, South Africa. The area's typical weather can be described as Mediterranean, with hot dry summers and cool winters. About 76% of the total long-term annual precipitation of 221 mm is recorded during winter (April-September) (Cloete *et al.*, 2007). Vegetation on the Nortier Experimental farm is type 34 – Strandveld as described by Acocks (1988), to which the lambs had *ad libitum* access.

Lambs were slaughtered according to standard South African procedures (Hoffman *et al.*, 2003) at 35 (± 8) days post weaning. Thirty minutes after slaughtering, dressing and evisceration, the carcasses were weighed to obtain hot carcass weight (HCW). After being cooled down for 24 h (4°C) the kidneys and channel fat were removed and weighed to obtain cold carcass weight. The carcasses were divided into the four retail cuts (leg, loin, rib, shoulder). The entire carcass of each lamb was analysed. Each retail cut (x 2 per carcass) was weighed and deboned. Meat and fat were separated by dissection and weighed. From these results muscle-fat-bone percentage yield was calculated as the weight of the tissue expressed as a percentage of the cold dressed carcass weight. It is important that the correct analytical method is used to assess muscle-fat-bone yield in sheep. Since only minor fat deposits are expected in the loin of the Namaqua Afrikaner, the composition of the three-rib cut would not necessarily be an accurate reflection of the Namaqua Afrikaner carcass.

An analysis of variance involving the general linear models (GLM) procedure of SAS (2002) was conducted on the different traits (percentage bone, percentage meat and percentage fat). Least square means (LSM) values were calculated and used to correct for the unbalanced data. R-square Type III P-values were used to test for significant differences. Results were corrected with slaughter age (153 ± 12 days) as covariate and a significance level of 95% was used as basis for all calculations.

3.3 Results and discussion

No differences (P > 0.05) were found between the breeds for percentage of fat and percentage of bone, when comparing the results of the complete carcasses (Table 3.1). This concurs with previous research where no differences were found between Dorper and SAMM carcasses in terms of percentage bone and fat yield (Webb & Casey, 1995). Results for percentage meat indicated that the carcass of the Namaqua Afrikaner contained less (P ≤ 0.05) meat than Dorper and SAMM carcasses. No differences (P > 0.05) were found between the Dorper and SAMM carcasses.

Table 3.1 Least square means (±SE) of percentage muscle-fat-bone yield of the Namaqua Afrikaner, Dorper and SAMM carcasses

Yield	**Breed**		
	NA^1 (n = 13)	**D^2 (n = 10)**	**SAMM^3 (n = 6)**
Percentage meat	44.8^b ± 0.81	51.3^a ± 0.91	51.3^a ± 1.21
Percentage fat	10.5 ± 0.85	13.9 ± 0.96	12.5 ± 1.28
Percentage bone	32.3 ± 2.46	29.8 ± 2.78	27.9 ± 3.68
Average carcass weight (kg)	10.5^b ± 2.27	17.4^a ± 2.31	17.1^a ± 2.14

[1] NA = Namaqua Afrikaner;
[2] D = Dorper;
[3] SAMM = South African Mutton Merino;
[ab] Means in the same row with different superscripts differ (P ≤ 0.05) (breeds).

The percentage muscle, fat or bone of the retail cuts did not differ (P > 0.05) between the Dorper and SAMM (Table 3.2). With the exception of the rib, the retail cuts of the Namaqua Afrikaner had a lower (P ≤ 0.05) percentage meat compared to the retail cuts of either the Dorper or SAMM (Table 3.2). The observed breed difference was particularly striking in the most expensive loin cut, where the Namaqua Afrikaner contained substantially less meat (44.9 ± 1.29%; P ≤ 0.05) than both the Dorper (52.8 ± 1.45%) and the SAMM (50.5 ± 1.92%). The percentage of meat in the leg of the Namaqua Afrikaner (61.4 ± 0.88%) was also lower (P ≤ 0.05) than the Dorper (68.0 ± 1.00%) leg cut, but compared favourably (P > 0.05) to the SAMM (65.3 ± 1.32%) leg cut. The shoulder of the Namaqua Afrikaner (45.3 ± 1.18%) had a lower (P ≤ 0.05) percentage of meat than that of the Dorper (50.3 ± 1.41%). The SAMM was intermediate and not significantly (P > 0.05) different from either of the other breeds for this cut (Table 3.2). This is according to expectations, as the late maturing Namaqua Afrikaner will have a lower percentage muscle than the early maturing Dorper at the same chronological age and should be similar to the late maturing SAMM with regards to meat yield.

Fat content of the different cuts were the only trait where no differences between the three breeds were found (Table 3.2), indicating that none of the breeds have reached maturity and that the fattening phase has not yet set in (Berg & Butterfield, 1968).

Even though no differences for percentage bone were found on comparison of the entire carcass (Table 3.1), differences were found on analysis of the separate retail cuts. In comparison with both the Dorper and SAMM, the Namaqua Afrikaner contained a higher ($P \leq 0.05$) percentage of bone in all of the retail cuts (Table 3.2). Again, this is according to expectations, as the late maturing Namaqua Afrikaner should have a higher percentage bone than the early maturing Dorper at the same chronological age. However, it was expected that the Namaqua Afrikaner would be more similar to the late maturing SAMM. When considering the results it is important to bear in mind that no selection for economically important traits have been done on the Namaqua Afrikaner and that the breed has not been genetically bred for meat production as both Dorper and SAMM were (Epstein, 1960; De Waal & Combrinck, 2000; Sheridan *et al*., 2003; Buduram, 2004).

Table 3.2 Least square means (±SE) of percentage muscle-fat-bone yield of Namaqua Afrikaner, Dorper and SAMM retail cuts

Yield	**Cut**	**Breed**		
		NA^1 (n = 13)	**D^2 (n = 10)**	**SAMM^3 (n = 6)**
Percentage Meat	Leg	$61.4^b \pm 0.88$	$68.0^a \pm 1.00$	$65.3^{ab} \pm 1.32$
	Loin	$44.9^b \pm 1.29$	$52.8^a \pm 1.45$	$50.5^a \pm 1.92$
	Rib	56.7 ± 2.41	63.1 ± 2.72	58.3 ± 3.60
	Shoulder	$45.3^b \pm 1.18$	$50.3^a \pm 1.40$	$49.0^{ab} \pm 1.76$
Percentage Fat	Leg	9.3 ± 0.70	8.5 ± 0.79	9.5 ± 1.05
	Loin	14.2 ± 1.17	17.7 ± 1.33	16.5 ± 1.76
	Rib	14.4 ± 2.40	18.5 ± 2.71	19.3 ± 3.58
	Shoulder	12.5 ± 1.14	16.1 ± 1.36	13.5 ± 1.71
Percentage Bone	Leg	$29.3^a \pm 0.70$	$23.5^b \pm 0.79$	$25.2^b \pm 1.04$
	Loin	$40.8^a \pm 1.20$	$29.6^b \pm 1.35$	$33.0^b \pm 1.79$
	Rib	$28.9^a \pm 0.92$	$18.4^b \pm 1.04$	$22.4^b \pm 1.38$
	Shoulder	$42.2^a \pm 0.99$	$33.7^b \pm 1.12$	$37.5^b \pm 1.48$
Average carcass weight (kg)		$10.5^b \pm 2.27$	$17.4^a \pm 2.31$	$17.1^a \pm 2.14$

^{1}NA = Namaqua Afrikaner;
^{2}D = Dorper;
^{3}SAMM = South African Mutton Merino;
^{ab} Means in the same row with different superscripts differ ($P \leq 0.05$).

Most of the differences in physical composition between the Dorper and Namaqua Afrikaner can be qualified by the fact that the Dorper is early maturing and the Namaqua Afrikaner late maturing (Epstein, 1960; Webb & Casey, 1995). Carcass composition can be described as the ratio to which the main tissues (muscle, fat, and bone) are found in a sheep carcass (Berg & Butterfield, 1968). Breed, age, nutrition and weight all affect the development of these tissues and their ratio relative to carcass weight (Berg & Butterfield, 1968). Development of different tissues/limbs/organs takes place in different stages, broadly sequenced chronologically as: central nervous system; bone; muscle; fat (Lawrie & Ledward, 2006). Although these stages progress simultaneously, the rate of development of each stage depends on its role in and importance to the survival of the animal.

According to Lawrie & Ledward (2006), the entire development process takes place in a shorter timespan for early maturing breeds than for late maturing breeds, indicating that the muscle: bone ratio of an early maturing breed should be higher than that of a late maturing breed at the same chronological age, until physiological maturity is reached by both. Furthermore, bone development takes preference over muscle and fat development (Lawrie & Ledward, 2006). The percentage of bone in the carcass will be higher at birth than at any other given time and the percentage of fat the lowest (Berg & Butterfield, 1968). As development continues the ratio of bone to carcass weight decreases while muscle ratio increases, and thus the muscle to bone ratio increases with an increase in carcass weight. Muscle tissue has the highest growth rate between birth and maturity (Berg & Butterfield, 1968). As maturity is reached the percentage of muscle to carcass weight will start to decrease as the percentage of fat starts to increase (fattening phase) (Berg & Butterfield, 1968). Thus it can be deduced that differences in the physical composition of certain cuts will be present, as influenced by age and degree of fatness (Lawrie & Ledward, 2006).

Only the rib-cut of the NA does not follow the expected pattern of comparison between late/early maturing breeds. Although Namaqua Afrikaner ram lambs contained a higher percentage of bone than the Dorper and the SAMM (Table 3.2), it compares well in terms of percentage meat with the other breeds. Differences in genetics and the size of cuts should be recognised here as possible explanation (Epstein, 1960; Berg & Butterfield, 1968). Buduram (2004) noted that the Namaqua Afrikaner breed shows very little polymorphism and is the most genetically different from the other indigenous and developed breeds, including the Dorper.

Mason and Maule (1960) have noted that a 20 kg Namaqua Afrikaner carcass can be reached at 12-18 months of age. Together with the differences in percentage of meat (loin cut) and bone yield between the Namaqua Afrikaner and also late maturing SAMM, it could be indicative of an even longer development cycle of the Namaqua Afrikaner carcass. From the high percentage of bone and low percentage of muscle in the Namaqua Afrikaner carcass it can be expected that the Namaqua Afrikaner is still growing bone and has not fully started with muscle development when slaughtered in the present study (Berg & Butterfield, 1968; Lawrie & Ledward, 2006).

3.4 Conclusions

Climate change may constrain the contribution of commercial sheep breeds such as the Dorper and SAMM in future, as constraints on food sources limit growth and development of animals, especially when not adapted to harsh conditions. With consumer preferences and purchase intent changing towards food products beneficial to health, lean meat is sought after thereby creating the possibility of marketing the leaner meat of the Namaqua Afrikaner as such. The Namaqua Afrikaner did not compare well with the Dorper for meat yield, but despite its carcass being smaller and containing a higher percentage bone than the SAMM carcass it performed better against the SAMM in terms of meat yield. Future research involving crossbreeding may elucidate the possibility of combining the hardiness of the Namaqua Afrikaner with early maturity in the Dorper and meat quality in the SAMM.

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CHAPTER 4

Comparison of the carcass composition of Namaqua Afrikaner and Dorper hoggets reared under extensive conditions

Abstract

This study evaluated the differences in the muscle-fat-bone yield of extensively raised hoggets; including an early maturing, commercially farmed meat breed (Dorper) and a late maturing, indigenous fat-tailed breed (Namaqua Afrikaner). Lambs were slaughtered at an average age of 16.7 months (502 days). Carcasses were cooled for 48 h post mortem, physical measurements of the carcass were taken, and thereafter separated into wholesale cuts (leg, loin, rib, and shoulder), weighed and deboned. After deboning, the fat was cut from the meat and meat, fat and bone were weighed separately to calculate percentage muscle-fat-bone yield. Least-square means were computed for the respective breeds, using slaughter age as covariate. Results for percentage meat indicated that the Namaqua Afrikaner compared favourably with the Dorper as no differences were found for any of the wholesale cuts ($P > 0.05$). With the exception of the leg cut, where no differences were found ($P > 0.05$), the Namaqua Afrikaner wholesale cuts contained a lower percentage of fat than the Dorper cuts ($P \leq 0.05$). The wholesale cuts of the Namaqua Afrikaner breed also carried a higher percentage bone than the Dorper cuts ($P \leq 0.05$). No differences were found for carcass length and width ($P > 0.05$), but the extremities of the Namaqua Afrikaner was both significantly longer and narrower in comparison with the Dorper ($P \leq 0.05$). The high bone yield, particularly in the more expensive loin and leg of the Namaqua Afrikaner could make it less preferred for meat production. However, since comparing favourably with the Dorper in terms of percentage meat yield as well as the lower percentage fat yield, crossbreeding programs with the Namaqua Afrikaner could be investigated. Differences as well as the similarities in carcass composition could be attributed to the combination of the Namaqua Afrikaner being a late maturing as well as an unimproved breed.

Keywords: Early maturing, indigenous, late maturing, muscle-fat-bone yield, unimproved, wholesale cuts, yearling

4.1 Introduction

By 2050 an increase of 60% in total global agricultural production is necessary to be able to meet the ever-growing demand for food (OECD/FAO, 2012); in the meat sector an increase increase in production of 200 million tonnes p.a. is required (OECD/FAO, 2013). Despite the negative health image created around the consumption of red meat (and the associated fatty acids) over the last 30 years (Higgs, 2000; Wood *et al.*, 2003), meat is considered a nutrient dense source of several vitamins and minerals key to a healthy lifestyle, as well as a source of essential amino acids (Warriss, 2000; Biesalski, 2005; Wyness *et al.*, 2011; Binnie *et al.*, 2014). Therefore, as part of finding strategies to improve dietary patterns in both developed and developing countries, consumption of nutrient dense foods such as lean red meat are recommended (Binnie *et al.*, 2014).

Against this backdrop, the South African red meat sector is seen as a vitally important growing industry – according to the latest information published by the Department of Agriculture, Forestry and Fisheries (DAFF, 2014); an increase of 11.8% in lamb and mutton production and 9.6% in consumption was observed over the last year (2012/2013) (DAFF, 2014) – with predictions indicating that this upward trend will last in the long term enabling supply to meet demand in the consumption of meat (BFAP, 2013).

Unfortunately the majority of South African sheep farms are located in either arid or semi-arid regions, limiting the production of mutton and lamb (DAFF, 2014). In addition, forecasts of global weather changes, inclined towards drier climates, presents further challenges to the South African agricultural sector as natural food resources for livestock are expected to decline (Turpie *et al.*, 2002; Vetter, 2009; West *et al.*, 2009; Willis & Bhagwat, 2009; Pio *et al.*, 2014). Also, the domestic meat market has been very volatile since 2012 and a record high was recorded for feed prices (BFAP, 2013). Thus, facing the difficulties of having to increase the production of lean meat but at the same time being handicapped by limitations in the use and availability of agricultural land, the possibility of farming with indigenous species, using modern technologies, has come to the attention of research communities (FAO, 2003; Van Marle-Köster *et al.*, 2013).

One such indigenous breed is the late maturing, fat-tailed Namaqua Afrikaner, regarded as one of the oldest sheep breeds in South Africa (Epstein, 1960; Snyman *et al.*, 1993; ARC, 2013) and well known for its ability to survive in arid climates (Epstein, 1960; Hugo, 1966; Epstein, 1971; Campbell, 1995; Ramsay *et al.,* 2001; Cloete & Olivier, 2010). Being indigenous to harsh environments the adaptive response of the Namaqua Afrikaner is to store surplus fat in a fat-tail rather than a thick subcutaneous fat (SCF) layer (Epstein, 1960; Almeida, 2011). Hence, the meat of the Namaqua Afrikaner can be considered lean as only minor inter- and intra-muscular fat depots are found (Epstein, 1960). Since the 1930's the Namaqua Afrikaner breed has fallen into commercial obscurity in South Africa and its development has been marked by natural, and to some extent unconscious selection, and its genetic composition was thus not influenced by selective breeding for the enhancement of commercially important traits, e.g. greater meat yield and improved eating quality (Epstein, 1960; Hugo, 1966; Zohary *et al*., 1998; Buduram, 2004; Snyman *et al.*, 2013).

The Dorper is currently considered the largest commercially farmed meat breed within South Africa (Cloete & Olivier, 2010). It has excellent carcass characteristics as its development is the result of selective breeding in favour of the improvement of meat quality (Webb & Casey, 1995; Brand, 2000; Milne, 2000; Ramsay *et al.,* 2001; Snowder & Duckett, 2003). Being an early maturing breed Dorper lambs can be slaughtered at a younger chronological age, but can also become too fat as a result of their faster growth rate and the development of subcutaneous fat depots (Cloete *et al.*, 2007).

The major tissues in a sheep carcass are its muscle (meat), fat and bone (Berg & Butterfield, 1968; Butterfield, 1988a; Cloete *et al.*, 2004a). Consequently carcass composition can be referred to as the different ratios, comparative to carcass weight, in which the major tissues are to be found in the carcass (Berg & Butterfield, 1968; Cloete *et al.*, 2004a). These tissues and the ratios thereof are constantly changing during the lifecycle of the sheep and are influenced by breed, age, nutrition and the weight of the animal (Berg & Butterfield, 1968). It is well known that the stage of maturity is closely related to body composition as early maturing breeds will reach the fattening phase at a younger chronological age and thus at a lower live weight than later maturing breeds (Pállson, 1955; Butterfield, 1988a, b; Lawrie & Ledward, 2006; Cloete *et al.*, 2012). With muscle being considered the most valuable tissue in the sheep carcass, determining differences in yield between breeds are thus of the utmost economic importance (Cloete *et al.*, 2004a).

In the previous chapter (Chapter 3) the carcass yield (muscle-fat-bone) of Namaqua Afrikaner lambs were compared with the carcass yield of Dorper and South African Mutton Merino (SAMM) lambs at the same chronological age. Results indicated that at approximately five months of age, the wholesale cuts of the Namaqua Afrikaner carcass differed from either or both breeds in terms of percentage muscle and bone yield ($P \leq 0.05$), but no differences were found in the percentage fat yield ($P > 0.05$) (Chapter 3; Burger *et al.*, 2013). It was concluded that the explanation can be found in the unimproved nature of the Namaqua Afrikaner in comparison to the Dorper and SAMM and secondly, in the differences in physiological age between the breeds (Chapter 3; Burger *et al.*, 2013).

Consequently it was decided to repeat the previous study with chronologically older lambs (hoggets), again studied for their lean meat production potential. The main objective of the current study was to determine whether or not the carcass yield of the unimproved, late maturing Namaqua Afrikaner will compare better at an older (both chronological and physiological) age with the improved, early maturing Dorper. The SAMM was not included in this trail as no SAMM hoggets were available.

4.2 Materials and methods

4.2.1 Experimental site

All of the hoggets involved in this study were raised in the same flock under extensive conditions at the Nortier Research farm (32°02'06.65"S; 18°19'55.52"E), situated near the town of Lamberts Bay on the Western coast of South Africa (Cloete & De Villiers, 1987; Cloete *et al.*, 2007). The area's climate can be described as Mediterranean – hot, dry summers with cool winters. Nortier Research farm lies within a winter rainfall region, with approximately 76% of the annual precipitation (221 mm) being recorded during the months of April to September (Cloete & De

Villiers, 1987; Cloete *et al.*, 2007). The flora at the site is regarded as a typical type 34 – Strandveld of the Western Seaboard, as described by Acocks (1988). The farm consists of 2800 ha with a stocking (flock) density of one lambs/sheep per five hectare (Rheeder, C. 2012, Farm Manager, Nortier Experimental farm, South Africa, personal communication, 4 May.).

4.2.2 Lamb management

The hoggets used in this study were born during the months of June and July 2011, with average birth weights being recorded within 24 hours of birth (Table 4.1). The lambs were nursed by their biological mothers and had the necessary *ad libitum* access to colostrum within the first 24h after birth. They grazed together with their dams under extensive conditions in a free range system, having *ad libitum* access to grazing (as described above) and water.

Being kept in a free-range system permitted the hoggets to complete daily natural exercise while busy foraging for food. The free range system allows for minimal stress as a result of human interaction/presence and the yearlings received vaccinations for the control of parasite infections according to standard sheep husbandry practices. They continued to roam with their dams until weaned on the 18th of October 2011 at an average age of ~110 days (109.5 ± 5.09 days and 110.4 ± 3.76 days for Namaqua Afrikaner and Dorper, respectively).

Table 4.1 Least square means (±SE) of the average weights and ages of the Namaqua Afrikaner and Dorper hoggets

Traits	**Breed**		
	Namaqua Afrikaner (n = 6)	**Dorper (n = 11)**	**p-value**
Birth weight (kg)	3.1 ± 0.28	3.7 ± 0.19	0.117
Weaning weight (kg)	17.6 ± 1.67	20.6 ± 1.24	0.168

4.2.3 Slaughter procedures

At 392 days (one year and 27 days) post weaning the animals were weighed and selected as slaughter ready (Table 4.1). As these weights were obtained 24 h before slaughter, it was used as slaughter weight. Average slaughter age of the hoggets was recorded as 501.5 ± 5.09 days and 502.4 ± 3.76 days for Namaqua Afrikaner and Dorper, respectively. The animals were transported by truck to Roelcor Abattoir, a commercial abattoir in Malmesbury (33°27’0S; 18°41’60E), a total distance of ≈250 km on a day with an average maximum temperature of 21.4°C and a maximum average relative humidity of 93%. There the hoggets were housed in overnight lairage (±16 h); with *ad libitum* access to water, but no food was provided. Slaughter procedures started the next morning at 7 am and were executed according to standard South African procedures (Hoffman *et al.*, 2003). Electrical stunning (4 s; 200 V) were used to render the hoggets unconscious, where after the stunned animals were suspended by the Achilles tendon and the jugular veins and carotid arteries severed with a single knife stroke, allowing bleeding (Cloete *et al*., 2004b). Carcasses were not electrically stimulated.

Immediately after exsanguination the carcasses were dressed and tagged with numbered tags to simplify identification for sample collection and moved into cold storage (4°C). After a cooling period of 48 h (4°C) the dressed carcasses were transported by refrigerated truck to the Meat Science Laboratory at the University of Stellenbosch, where they were kept at refrigeration temperatures (4°C) until deboning and sampling took place.

4.2.4 Physical measurements

4.2.4.1 Carcass measurements

Measurements were taken as described by Cloete *et al.* (2012), with adaptations to the process as described below. Using handheld callipers the carcass measurements were taken while the carcass was suspended from both hind limbs. Carcass length was measured from the ischium (hip bone) to the proximal end of the humerus. The depth of carcass was measured straight across, from the first rib (posterior to the sternum) to the dorsal end of the thoracic vertebrae (feather bones). Carcass (back) width was measured across the back, at the widest point on the ilium. The length of the hind limb (leg) was measured from the anterior end of the pubis to the distal end of the tibia. The fore limb (shoulder) length was measured from the scapula to the distal ends of the radius and ulna. The width of both limbs was measured across the widest point of each limb: hind limb was measured across the leg muscle and the fore limb across a line running across the widest point of the scapula.

4.2.4.2 Subcutaneous fat measurements

The thickness of the subcutaneous fat layer (SCF) of each carcass was measured to determine the SCF fat depth. Measurements were taken with a handheld electronic calliper (mm) at two different sites on the left *longissimus lumborum*, 25 mm off the midline of the spine. The first site was located at the 13th rib (Gilmour *et al.*, 1994) and the second between the 3rd and 4th lumbar vertebrae (Bruwer *et al.*, 1987) of each carcass.

4.2.5 Measurement of wholesale cuts

Partitioning into the different cuts (Fig. 4.1) and the deboning thereof took place as described by Cloete *et al.* (2004a, b, 2012), with minor changes to the procedure. After being suspended from both hind legs for 48 h (4°C) the carcasses were weighed and divided into wholesale cuts (leg, loin, rib, shoulder, neck and tail). The fat-tails of the Namaqua Afrikaner were removed by cutting through the coccygeal vertebrae, perpendicular to the spine. Cutting at a right angle through the spine, the neck was dislodged from the carcass at the seventh cervical vertebrae. Second, following the curve of the leg muscle, the abdominal wall was cut loose from the inside of the hind limb. The hind limbs (legs) were removed by cutting along a line perpendicular to the ilium, running through the sixth lumbar vertebrae. The remaining part of the carcass was sawed in half and the fore limbs (shoulders) were removed by cutting from the elbow (olecranon) joint on a line following the curve of the shoulder muscle and perpendicular to the spinal column, to a point between the proximal end of the fifth and sixth ribs. The ribs were separated from the loin on a line running parallel to the spinal column, leaving the *longissimus thoracis et lumborum* intact.

All of the cuts were weighed prior to deboning by a team experienced in the deboning of carcasses. Thereafter all fat was removed from the muscles and meat and fat was weighed separately (Cloete *et al.* 2004a, b, 2012). Weighing was done on a digital computing scale, accurate to the nearest gram.

Wholesale cuts used in this study comprised of the following: leg (proximal and distal hind limb); loin (muscles surrounding the spinal column); rib (thorax to forelimb and abdominal wall) and shoulder (proximal and distal fore limb), as depicted by Butterfield (1988a) (Fig. 4.1).

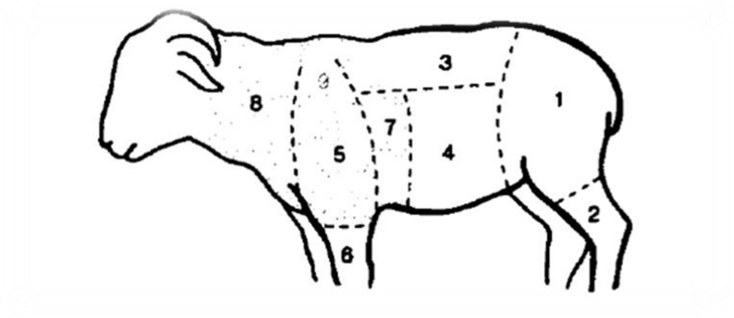

Figure 4.1 The total musculature comprised by the "Standard Muscle Groups" as adapted from Butterfield (1988a). Muscle groups are: 1. Proximal hind limb; 2. Distal hind limb; 3. Surrounding spinal column; 4. Abdominal wall; 5. Proximal forelimb; 6. Distal forelimb; 7. Thorax to forelimb; 8. Neck to forelimb.

4.2.6 Statistical analyses

An analysis of variance (ANOVA) using the GLM (General Linear Models) procedure of SAS™ statistical software (Statistical Analysis System, Version, 9.2, 2006, SAS Institute Inc., Cary, NC, USA) was conducted on the different traits. Outliers were determined and removed before the final ANOVA was considered. Least square means (LSM) values (± SE) were calculated and used to correct for the unbalanced data. R-square Type III P-values were used to test for significant differences. Results were corrected with slaughter age (502 days) as covariate and a significance level of 95% was used as basis for all calculations. Results were also corrected with carcass weight as covariate.

4.3 Results and discussion

When studying the Namaqua Afrikaner it is important to consider its unimproved nature, which is fundamental to determining the causes for the similarities or differences found when it is compared to other sheep breeds (Hugo, 1966; Buduram, 2004; Snyman *et al.*, 2013). In the current study the research of the previous chapter (Chapter 3) was repeated on hoggets to determine whether the carcass yield of the Namaqua Afrikaner will compare more favourable with that of the Dorper at a later stage of both chronological and physiological development. Upon comparison of slaughter weight the Namaqua Afrikaner (39.2 ± 2.90 kg) weighed less ($P = 0.012$) than the Dorper (49.7 ± 2.14 kg) (Table 4.2). When comparing carcass weight, the Namaqua Afrikaner carcass (14.3 ± 1.43 kg) does not compare well with the Dorper carcass (22.8 ± 1.06 kg; $P < 0.001$). Neither does dressing percentage with the Namaqua Afrikaner only achieving 36.5 ± 0.60 %, while the Dorper averaged 45.8 ± 0.44 % ($P < 0.001$) (Table 4.2). The results of the composition of the complete carcass indicated breed differences observed for the percentage meat, fat and bone yield ($P \leq 0.05$) (Table 4.3). Results for total percentage lean meat yield indicated that the Namaqua Afrikaner carcass (49.3 ± 1.12%) carried less meat than the Dorper carcass (52.5 ± 0.83%; $P = 0.040$). However upon analysis of the separate cuts, no differences were found in percentage lean meat yield of these cuts ($P > 0.05$) (Table 4.3). The Namaqua Afrikaner carcass (excluding the fat-tail) also contained significantly less fat (14.2 ± 1.41%) and more bone (28.7 ± 0.55%) than the Dorper (21.5 ± 1.04%, $P < 0.001$; 21.2 ± 0.40%, $P < 0.001$) (Table 4.3).

When analysing the percentage contribution of the weight of each wholesale cut to the total carcass weight, it was noted that the leg and shoulder cuts of each breed contribute similar in percentage weight to total carcass weight ($P > 0.05$) (Table 4.4). However, both the loin (*longissimus thoracis et lumborum*) (19.0 ± 0.75%) and rib (10.2 ± 0.62%) cuts of the Namaqua Afrikaner contributed a smaller percentage to the total carcass weight than the Dorper's loin (21.7 ± 0.55%; $P = 0.011$) and rib (13.7 ± 0.46%; $P < 0.001$) cuts (Table 4.4) – an important finding as the loin cut is considered the most expensive cut in the carcass.

Table 4.2 Least square means (±SE) of carcass characteristics of the Namaqua Afrikaner and Dorper hoggets

Carcass characteristics	Breed		p-value
	Namaqua Afrikaner (n = 6)	Dorper (n = 11)	
Slaughter weight (kg)	39.2 ± 2.90	49.7 ± 2.14	0.012
Carcass weight (kg)	14.3 ± 1.43	22.8 ± 1.06	<.001
Dressing percentage (%)	36.5 ± 0.60	45.8 ± 0.44	<.001
Total carcass length (cm)	178.8 ± 2.14	184.1 ± 1.65	0.072
Carcass depth (cm)	29.1 ± 0.71	27.7 ± 0.50	0.121
Carcass width: back (cm)	14.0 ± 0.71	18.0 ± 0.55	<.001
Leg length: hind limb (cm)	55.6 ± 1.73	49.1 ± 1.34	0.011
Leg width: hind limb (cm)	18.9 ± 0.96	22.3 ± 0.74	0.015
Shoulder length: fore limb (cm)	46.6 ± 1.76	40.0 ± 1.37	0.012
Shoulder width: fore limb (cm)	14.8 ± 0.49	20.2 ± 0.38	<.001
Fat depth: 13th rib (mm)	1.1 ± 0.33	3.7 ± 0.36	<.001
Fat depth: 3rd & 4th lumbar vertebrae	3.3 ± 0.99	8.4 ± 1.09	0.009
Weight of tail (g)	425.0 ± 57.83	Docked	-

Measurements of the carcasses were also recorded and no breed differences were observed in the length and depth of the carcasses (Table 4.2). In contrast results found in literature reported the Namaqua Afrikaner carcass to be significantly longer than that of the Dorper (Snyman *et al.,* 1996). However, the results indicated that the carcass width of the Namaqua Afrikaner (14.0 ± 0.71 cm) carcass is less than the Dorper (18.0 ± 0.55 cm; $P < 0.001$) (Table 4.2). Visual observations also confirmed this and it was noted that the back of the Namaqua Afrikaner is narrow and ridge-like, whereas the Dorper, in comparison, has a flat, broad back (Fig. 4.2). Similar results were found by Snyman *et al.* (1996), who stated that in comparison the Dorper has a more square body conformation, whereas the Namaqua Afrikaner has a longer and narrower conformation typical of an animal adapted to hotter climates (Marai & Habeeb, 1998; Lawrie & Ledward, 2006).

The hind limb (leg) and fore limb (shoulder) of the Namaqua Afrikaner (55.6 ± 1.73 cm; 46.6 ± 1.76 cm) were both longer than the Dorper's limbs (49.1 ± 1.34 cm, $P = 0.11$; 40.0 ± 1.37 cm; $P = 0.12$), but the width of the Namaqua Afrikaner's limbs (18.9 ± 0.96 cm; 14.8 ± 0.49 cm) were less than the Dorper's limbs (22.3 ± 0.74 cm, $P = 0.015$; 20.2 ± 0.38 cm, $P < 0.001$) (Table 4.2).

Also, significant differences were found in the thickness of the subcutaneous fat layer. The SCF depths of the Namaqua Afrikaner were significantly less at both the 13th rib ($P < 0.001$) and the 3rd and 4th lumbar vertebrae ($P = 0.009$) (Table 4.2).

Table 4.3 Least square means (±SE) of percentage muscle-fat-bone yield of Namaqua Afrikaner and Dorper wholesale cuts and the total yield per carcass (with slaughter age as covariate)

Yield	**Cut**[#]	**Breed**		**p-value**
		Namaqua Afrikaner (n = 6)	**Dorper (n = 11)**	
Total yield	% Meat	49.3 ± 1.12	52.5 ± 0.83	0.040
	% Fat	14.2 ± 1.41	21.5 ± 1.04	<.001
	% Bone	28.7 ± 0.55	21.2 ± 0.40	<.001
% Meat (per cut)	Leg	63.4 ± 1.34	66.7 ± 0.99	0.066
	Loin	45.1 ± 2.17	47.4 ± 1.60	0.422
	Rib	44.0 ± 2.61	46.4 ± 1.93	0.466
	Shoulder	51.9 ± 2.20	53.8 ± 1.63	0.506
% Fat (per cut)	Leg	12.9 ± 1.65	15.0 ± 1.22	0.334
	Loin	18.9 ± 2.21	26.4 ± 1.60	0.016
	Rib	26.4 ± 2.77	36.6 ± 2.04	0.010
	Shoulder	12.2 ± 1.63	20.7 ± 1.20	<0.001
% Bone (per cut)	Leg	23.7 ± 0.87	18.3 ± 0.65	<0.001
	Loin	36.0 ± 1.24	26.2 ± 0.91	<0.001
	Rib	29.6 ± 0.92	17.0 ± 0.68	<0.001
	Shoulder	35.9 ± 1.24	25.5 ± 0.91	<0.001
Muscle: Bone ratio (per carcass weight)		1.7 ± 0.15	2.6 ± 0.12	<0.001

[#] The neck cuts were not included in this part of the study.

Table 4.4 Least square means (±SE) of percentage of the percentage of carcass weight that each cut constitute for Namaqua Afrikaner and Dorper wholesale cuts

Size of cut = % of carcass weight	**Breed**		**p-value**
	Namaqua Afrikaner (n = 6)	**Dorper (n = 11)**	
Carcass weight (kg)	14.3b ± 1.43	22.8 ± 1.06	<.001
Leg (%)	30.9 ± 0.94	30.3 ± 0.70	0.589
Loin (%)	19.0 ± 0.75	21.7 ± 0.55	0.011
Rib (%)	10.2 ± 0.62	13.7 ± 0.46	<.001
Shoulder (%)	32.0 ± 1.18	29.4 ± 0.87	0.095
Neck (%)	5.7 ± 0.22	4.2 ± 0.17	<.001
Tail (%)	3.4 ± 0.21	0.5 ± 0.15	<.001

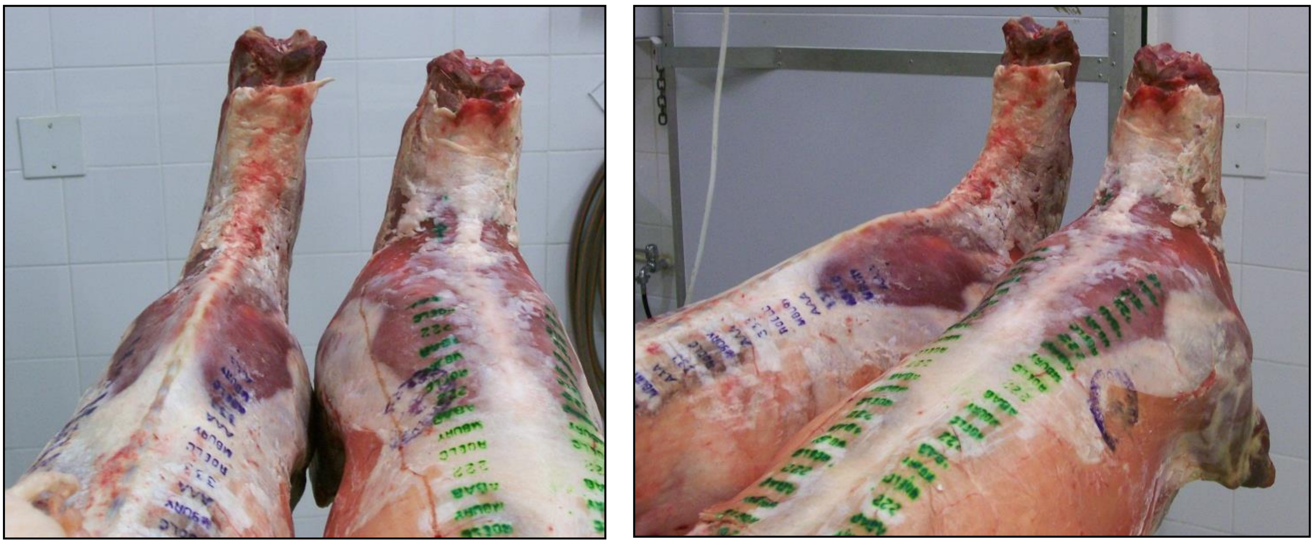

Figure 4.2 Visual comparison of body composition of Namaqua Afrikaner (left) and Dorper (right) carcasses – narrow, ridge-like back of the Namaqua Afrikaner and the flat, broad back of the Dorper can be seen.

In the previous study (Chapter 3) it was determined that in terms of percentage dissected lean meat yield the leg, loin and shoulder cuts of the Namaqua Afrikaner lambs (average five months old) did not compare favourably with the same cuts from the Dorper. Only the rib cut compared favourably with that of the Dorper (Burger *et al.*, 2013). In contrast, the results of the present study indicated that the Namaqua Afrikaner hoggets performed well against Dorpers of a similar age for percentage dissected lean meat yield as no breed differences were found for any of the wholesale cuts (P > 0.05) (Table 4.3).

Also, in the previous study no differences were found between the breeds for percentage fat yield (excluding the fat-tail of the Namaqua Afrikaner) (P > 0.05) (Chapter 3; Burger *et al.*, 2013). However, in the current study and consistent with expectations, the loin (18.9 ± 2.21%), rib (26.4 ± 2.77%) and shoulder (12.2 ± 1.63%) cuts of the yearling Namaqua Afrikaner yielded considerably less fat than the same cuts of the Dorper (26.4 ± 1.60%, P = 0.016; 36.6 ± 2.04%, P = 0.010; 20.7 ± 1.20%, P < 0.001) (Table 4.3). Only in the results of the leg cut were no differences observed between Namaqua Afrikaner (12.9 ± 1.65%) and Dorper (15.0 ± 1.22%; P 0.334) (Table 4.3).

The results for percentage bone yield were similar to that of the previous study (Chapter 3; Burger *et al*., 2013): for each of the wholesale cuts (leg, loin, rib, shoulder) where the percentage bone yields were substantially higher in the Namaqua Afrikaner cuts (23.7 ± 0.87%; 36.0 ± 1.24%; 29.6 ± 0.92%; 35.9 ± 1.24%) than in the same cuts of the Dorper hoggets (18.3 ± 0.65%, P < 0.001; 26.2 ± 0.91%, P < 0.001; 17.0 ± 0.68%, P < 0.001; 25.5 ± 0.91%, P < 0.001) (Table 4.3).

As with the younger lambs (Chapter 3; Burger *et al*., 2013), the majority of the results can be explained by the unimproved nature of the Namaqua Afrikaner as well as the difference between the two breeds in their time taken to reach physiological maturity – with the Namaqua Afrikaner being a late maturing breed (Epstein, 1960) and the Dorper an early maturing breed (Webb & Casey, 1995; Cloete *et al.*, 2000; Milne, 2000; Cloete *et al.*, 2007).

All animals do not grow and develop at the same rate and hence do not reach maturity at the same chronological age (Pállson, 1955; Beitz, 1985; Warriss, 2000; Irshad *et al.*, 2012). Growth (actual weight gain) will initially start out slow, but will continue to accelerate until a maximum rate of gain is attained when body weight reaches an average of 30% of the mature weight, which also generally coincides with reaching puberty (Beitz, 1985; Warriss, 2000). Subsequently, as the animal ages, a decrease in available space for tissue growth occurs and the rate of weight gain will slow down (Beitz, 1985; Warriss, 2000).

The intensity of growth of the animal's different carcass tissues also differ (Irshad *et al.,* 2012). Pállson (1955) has identified four main stages of development (cell differentiation or differential growth) which can be broadly summarised chronologically as: central nervous system; bone; muscle and fat (Lawrie & Ledward, 2006). These stages begin and progress simultaneously until physiological maturity is reached by the animal, but the rate of progression of each stage will be determined by its importance to and role in the survival of the animal (Pállson, 1955; Butterfield, 1988a; Warriss, 2000). Initially skeletal (bone) development is given priority over muscle and fat development, but as the animal continues to grow and develop the ratio of bone to muscle and carcass weight continuously decreases (Pállson, 1955; Warriss, 2000). The opposite is true for the ratio of fat in the body. Of the three major tissues muscle has the highest growth rate from birth to maturity. Upon reaching maturity, the ratio of muscle to carcass weight will start to decrease, whereas the ratio of fat tissue to carcass weight will increase as the fattening phase sets in (Berg & Butterflied, 1968; Butterfield, 1988a).

However, within species differences can be observed as animals from different breeds will grow and develop at different rates, and will therefore not reach physiological maturity at the same chronological age (Warriss, 2000; Lawrie & Ledward, 2006; Irshad *et al.*, 2012). An early maturing breed's entire development cycle will occur and reach conclusion within a shorter chronological time span than a late(r) maturing breed (Pállson, 1955; Lawrie & Ledward, 2006). Hence it can be deduced that at any chronological age, until physiological maturity is reached by both breeds, the muscle to bone ratio of an early maturing breed will be higher than that of a late maturing breed (Pállson, 1955; Lawrie & Ledward, 2006). Also, as an animal approaches maturity, the smaller the growth increments of the different tissues become; this is due to the sigmoidal shape of the growth curve (Butterfield, 1988a; Warriss, 2000). Sheep puberty can set in from between five to twelve months of age, depending on breed and is also influenced by body weight (Cooper, 2012). According to Ramsay *et al*. (2001), Namaqua Afrikaner ewes reach sexual maturity at nine and a half months. In contrast Dorper ewes can reach puberty as young as six months (Ramsay *et al.*, 2001) and Greeff *et al.* (1988) reported that maiden Dorper ewes could reach first oestrus at 7 months (213 days) at a live weight of 39 kg. Snyman *et al*. (2005) stated that the age of first lambing for Namaqua Afrikaner ewes are on average 16.5 months, whereas the first age of lambing for Dorpers can be as early as 11.5 months (346 days) (Greeff *et al.*, 1988).

Furthermore, Hammond (1961) noted that the ultimate length of the skeletal bones define the size of the individual muscles that will develop around these bones, and so also define the final quantity of edible meat that could be obtained from of the carcass (Berg & Butterfield, 1968). Therefore, although the width of the wholesale cuts (leg and shoulder) of the Namaqua Afrikaner were significantly less than that of the Dorper (Table 4.2), the longer length of the same cuts allowed for the Namaqua Afrikaner's muscles to grow to an adequate size at which a favourable comparisons with the Dorper could be reached (Table 4.3).

McClelland and Russel (1972) and Butterfield (1988b) established that when animals are slaughtered at the same physiological age, even though differences in carcass weight can be expected, results for the yield of percentage fat in the body should not be significantly different. In contrast to these results, differences in the percentage fat as well as percentage bone yield were found in the current study ($P \leq 0.05$) (Table 4.3), indicating that the hoggets were not at a similar physiological stage. As a further substantiation of this deduction, the loin, rib and shoulder cuts of the Namaqua Afrikaner contained significantly less fat than did the same cuts of the Dorper hoggets ($P \leq 0.05$) (Table 3). As all of the animals were raised together under the same conditions, these outcomes can be attributed to breed (physiological) differences (genetics) (Butterfield, 1988b): the Dorper is an early maturing breed and the Namaqua Afrikaner late maturing (Epstein, 1960; Webb & Casey, 1995; Cloete *et al.*, 2000; Milne, 2000; Cloete *et al.*, 2007). As mentioned, owing to limitations on the availability of space for further physical growth after maturity has been reached, the ratio of muscle to carcass weight will start to decrease and the ratio of fat to carcass weight will increase (Beitz, 1985; Warriss, 2000). Hence, it can be reasoned that the Dorper hoggets used in the current study had a longer (chronological) period of time to deposit fat in the body, partially explaining the differences in yield.

Secondly, and perhaps of greater importance, is the dissimilarities in the localities of fat depot's in the bodies of these the two breeds, particularly in the subcutaneous and caudal regions (Epstein, 1960; Hugo, 1966; Brand, 2000; Milne, 2000; Ramsay *et al.,* 2001; Almeida, 2011). Being indigenous to severely arid environments the Namaqua Afrikaner breed has responded with the adaptive trait of storing surplus fat/energy in a fat-tail, rather than in a thick subcutaneous fat layer, as in the case with imported or developed breeds (Epstein, 1960; Hugo, 1966). Consequently, when maturity is reached and the fattening phase sets in, the Namaqua Afrikaner will store the bulk of its surplus fat in its fat-tail, with only minor fat deposits (in comparison) to be found in the rest of the carcass – as opposed to the Dorper being docked and storing surplus fat subcutaneously (Fig. 4.3) (Epstein, 1960; Mason & Maule, 1960; Epstein, 1971). These results conform to expectations and are supported by the measurements of the fat depth of the SCF – measured at both sites the fat depth of the Namaqua Afrikaner is less than the Dorper's ($P \leq 0.05$) (Table 4.2). As previously mentioned, consumption of unprocessed, lean red meat within dietary recommendations are advantageous to a healthy lifestyle, therefore the leanness of the Namaqua Afrikaner meat can be considered a positive attribute (Biesalski, 2005; Elango *et al.*, 2012; Binnie *et al.*, 2014).

However, if the data is analysed with "carcass weight" as covariate, the results for both the loin and rib cuts changed in agreement with McClelland and Russel's (1972) and Butterfield's (1988b) statement (as discussed) – no differences were observed between the two breeds ($P > 0.05$) (Table 4.5).

The leg cut of the Namaqua Afrikaner (12.9 ± 1.65%) did not conform to the aforementioned trend and yielded the same quantity of fat as the Dorper leg (15.0 ± 1.22%; $P = 0.334$) (Table 4.3). Butterfield (1988a) provided a possible explanation when he noted that the hind leg of a sheep is early maturing in comparison to several of the other components in the body. Therefore, even though the Namaqua Afrikaner is late maturing (Epstein, 1960), in comparison with the rest of its body, the hind leg would have reached maturity sooner. Furthermore, the proximity of the hind leg to the fat-tail could also indicate that to some extent surplus energy (fat) intended for the fat-tail depot was deposited in the subcutaneous fat tissue in the proximal region of the hind leg (Fig. 4.3).

From a sensory perspective the greater quantity of fat observed in the leg of the Namaqua Afrikaner can be regarded as favourable as research has indicated that there is a positive correlation between the fat content of meat cuts and the flavour, juiciness and (perceived) tenderness of the meat (Chapter 6) (Warriss, 2000). The implication of this is that consumers should perceive the leg cuts of the two breeds as not significantly different in terms of flavour (on condition that both breeds consume similar grass and forb species), juiciness and tenderness. Thus, it can be said that the Namaqua Afrikaner leg performs well against that of the Dorper from an economical (percentage meat yield) and possibly also from a sensory (percentage fat yield) perspective.

Figure 4.3 Differences in subcutaneous and tail-fat distribution can be observed in the two Namaqua Afrikaner carcasses (left) and the two Dorper carcasses (right).

As in the previous study (Chapter 3; Burger *et al*., 2013) and in contrast to initial expectations, all the wholesale cuts of the Namaqua Afrikaner contained a higher percentage of bone than the same cuts of the Dorper ($P \leq 0.001$) (Table 4.3). The most likely explanation can be found in the unimproved nature of the Namaqua Afrikaner (Hugo, 1966; Buduram, 2004; Snyman *et al*., 2013). Several authors (Epstein, 1960; Hugo, 1966; Epstein, 1971; Ramsay *et al.,* 2001) have commented on the length of the Namaqua Afrikaner's limbs, developed as a result of being indigenous to arid regions and having to walk substantial distances to find sufficient grazing and water (Epstein, 1960; Hugo, 1966; Epstein, 1971; Campbell, 1995; Ramsay *et al.,* 2001; Cloete & Olivier, 2010). Zohary *et al.* (1998) explained that as a result of domestication changes in selection pressures took place, resulting in changes in the morphology, behaviour and physiology of animals. This will include a shortening of the legs relative to the size of the body, as a result of not having to maintain the physical ability to evade or confront predators or navigating a rough and hilly terrain (Zohary *et al*., 1998). Being unimproved the Namaqua Afrikaner's limbs have been less exposed to this inclination in selection than the Dorper, as can be seen in the results of the length of the extremities (Table 4.2 & Fig. 4.4).

Figure 4.4 Visual observations of differences in length of extremities between same aged Dorper (left) and Namaqua Afrikaner lambs

However, with carcass weight as covariate, the leg cut of the Namaqua Afrikaner compared favourably with the Dorper (P > 0.05) (Table 4.5), confirming the contention by Butterfield (1988a) that the hind leg grows and matures faster than certain other tissues (as discussed).

Table 4.5 Least square means (±SE) of percentage muscle-fat-bone yield of Namaqua Afrikaner and Dorper wholesale cuts – comparison of slaughter age and carcass weight as covariant[#]

Yield	Cut	Slaughter age			Carcass weight		
		Namaqua Afrikaner	Dorper	p-value	Namaqua Afrikaner	Dorper	p-value
% Fat	Loin	18.9 ± 2.21	26.4 ± 1.60	0.016	21.7 ± 2.92	24.9 ± 1.90	0.457
	Rib	26.4 ± 2.77	36.6 ± 2.04	0.010	30.3 ± 2.86	32.7 ± 1.96	0.057
% Bone	Leg	23.7 ± 0.87	18.3 ± 0.65	<0.001	22.2 ± 1.13	19.2 ± 0.74	0.081

[#] No differences in results were found between the two co-variants for all other wholesale cuts

Furthermore, being early maturing and as the Dorper is clearly nearer to physiological maturity, the percentage bone in its carcass should be lower in comparison as it has decreased further in ratio to carcass weight, as it is known that as carcass weight increases, percentage bone will decrease (Pállson, 1955; Butterfield, 1988a; Warriss, 2000; Lawrie & Ledward, 2006). This is supported by the muscle: bone ratio, with the Namaqua Afrikaner (1.7 ± 0.15%) presenting a lower ratio than the Dorper (2.6 ± 0.12%; P < 0.001) (Table 4.3). This also agrees with the results of the previous study (Chapter 3; Burger *et al.*, 2013), in which the wholesale cuts of the Namaqua

Afrikaner were also compared to that of the later maturing SAMM breed (Webb & Casey, 1995). With the exception of the loin cut, the Namaqua Afrikaner's percentage meat yield compared favourably with that of the late maturing SAMM breed (Chapter 3; Burger *et al.*, 2013). However, in contrast to expectations, when percentage bone was compared for the two breeds, the Namaqua Afrikaner did not perform well against the SAMM. For that reason the postulation was given that these results, and specifically the differences in percentage bone yield, could be indicative of an even longer growth cycle for the Namaqua Afrikaner than previously accepted (Chapter 3; Burger *et al*., 2013).

Therefore, it seems that the Namaqua Afrikaner slaughtered in the present study could still be in the muscle development phase and that the ratio of bone to carcass weight has not yet had sufficient time to decrease to an more acceptable level (Pállson, 1955; Berg & Butterfield, 1968; Warriss, 2000; Lawrie & Ledward, 2006). Furthermore, the possibility exists that the higher weight of the bones in the Namaqua Afrikaner carcass could be attributed to a higher bone density. Future research with regard to bone density will be able to shed light on this statement.

4.4 Conclusions

With the agricultural sector facing numerous challenges in having to increase meat production, while keeping input resources the same, farming with indigenous breeds are being investigated as a solution. The lean meat of the Namaqua Afrikaner is seen as a positive attribute, with consumer preferences and purchase intent favouring the consumption of lean red meat. Although its higher bone yield counts against the Namaqua Afrikaner, it compared favourably with the Dorper in terms of meat yield at an older physiological age. In addition, the Namaqua Afrikaner carcass carried significantly less fat than the Dorper in all of the wholesale cuts, except for the leg cut. While the measurements of the carcasses indicated that the width of the Namaqua Afrikaner limbs were less than that of the Dorper, the length thereof were greater than the limbs of the Dorper carcasses. Being a sign of its hardiness, the longer bone length allowed the Namaqua Afrikaner sheep to develop muscle quantity similar to that in the Dorper carcass. As a result future research on crossbreeding with the Namaqua Afrikaner could elucidate the possibility of combining the important attributes of the Namaqua Afrikaner, such as its hardiness, with the meat producing qualities of the Dorper.

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CHAPTER 5

Meat quality and proximate composition of the Namaqua Afrikaner, Dorper and South African Mutton Merino and respective crossbred lambs

Abstract

Researchers have begun to investigate the possibilities of farming with indigenous breeds – presumably well adapted to the harsh climates in South Africa – as a result of the potential influence of the current changes in weather patterns on the sustainability of South African agriculture and specifically lamb/mutton production. At the moment there is no information available on the meat quality and proximate composition of the indigenous fat-tailed Namaqua Afrikaner relative to alternative commercial breeds. The aim of this study was thus to compare the meat quality of the Namaqua Afrikaner to that of the Dorper and South African Mutton Merino (SAMM); respectively South Africa's main commercial meat and dual-purpose breeds. Lambs from the Namaqua Afrikaner x Dorper (NA x D) and SAMM x Dorper (SAMM x D) crosses were also included in the study, as the possibility existed that the desired combination of sought after traits may be present in crossbred progeny. These lambs were reared in the West Coast Strandveld at the Nortier Research farm (32°02'06.65"S; 18°19'55.52"E). The site has a Mediterranean climate (dry, hot summers and cool winters); with an average annual precipitation of 221 mm mostly between April and September. Lambs were selected on visual appraisal as being ready for slaughter. A completely randomised design with factorial arrangement of the treatments was used with breed and production year (2010-2012) as main effects. Breed differences were observed for most of the attributes measured, including subcutaneous fat depth, pH and percentage cooking loss. An interaction between breed and production year were observed for muscle drip loss and colour (L*, a* and hue values). Overall the results of the Namaqua Afrikaner compared favourably with the also late-maturing SAMM. The intramuscular fat content of the Namaqua Afrikaner (1.7 ± 0.08%) were significantly less than any of the other purebred (Dorper 2.2 ± 0.05%; SAMM 2.2 ± 0.13%) or the crossbred genotypes (NA x D 2.4 ± 0.09%; SAMM x D 2.8 ± 0.11%). Most notable was that no breed differences were observed for muscle shear force (average 49.3 ± 0. 85 N), implying that despite having a lower intramuscular fat content, the meat of the Namaqua Afrikaner (53.1 ± 1.73 N) were comparable to the commercial meat breeds in terms of tenderness; regarded as one of the most important attributes in the sensory profile of meat.

Keywords: Carcass characteristics, early maturing, indigenous, late maturing, physical attributes, proximate composition, unimproved

5.1 Introduction

Despite the fact that the trends in the demand for red meat are continuously changing, consumers' expectations of receiving good value for their money does not change (Troy & Kerry, 2010; Henchion *et al.*, 2014). While the global red meat industry used to be predominantly production driven, it has been changing towards being driven by consumer satisfaction (Issanchou, 1996; Troy & Kerry, 2010). Product quality is becoming more and more important as a driver in consumer purchase-intent and behaviour (Henchion *et al.*, 2014). Luning and Marcelis (2009) describe quality as representative of a product's attributes which will meet both the physiological and/or psychological needs of a consumer, while Molnár (1995) expands on this when stating that the safety, nutritional value, convenience and sensory properties of a product determines its quality.

Appearance (colour, exudate and visible fat i.e. marbling and subcutaneous) of the meat is the only quality attribute that can be assessed before purchase (Warriss, 2000a; Grunert *et al.,* 2004) and for this reason the appearance of a product is of great commercial value as it influences the first impressions created of said product. Acceptance based on the colour of the meat has been well documented by numerous authors (Jeremiah *et al*. 1972; Grunert, 2006) and colour is often used as an indicator of freshness (Issanchou *et al.*, 1996; Grunert, 2006). Appearance cues such as visible drip or exudate in meat packaging will have an adverse effect on the overall appearance of the product, while associating with negative results for the perceived juiciness of the product (Issanchou, 1996; Warriss, 2000a), subsequently affecting consumer acceptability (Troy & Kerry, 2010). In addition, exudate formation is also indicative of weight loss – implying a smaller quantity of product available for sale/consumption, thus influencing its commercial value (Offer & Trinick, 1983). As a result meat manufacturers are trying to keep drip loss formation as low as possible (Huff-Lonergan & Lonergan, 2005).

Many consumers regard the tenderness of meat as its most important quality attribute, which seems to influence the re-purchasing intent of the consumers (Whipple *et al.,* 1990; Warriss, 2000a; Pietrasik & Shand, 2004). Furthermore, the positive correlation between meat tenderness and intramuscular fat (IMF) content is well known. As the IMF content increases, its physical effect of "diluting" the intramuscular connective tissue can be observed, resulting in (perceivably) more tender meat (Schönfeldt *et al.*, 1993; Warner *et al.*, 2010; Yousefi *et al.*, 2012).

The proximate chemical composition of meat is representative of its nutritional value (Higgs, 2000). Red meat is considered to be nutrient dense, being a rich source of essential key nutrients, including bioavailable minerals (iron, zinc, selenium and potassium), vitamins A and B (thiamine, riboflavin, B12) as well as high quality proteins (Warriss, 2000a; Biesalski, 2005; Wyness *et al.*, 2011; Binnie *et al.*, 2014). The bioavailability of the iron, as well as its ability to enhance the absorption of non-haem iron from plant sources when consumed together, is regarded as one of the most important nutritional benefits of red meat (Cook & Monsen, 1976; Higgs, 2000; Warriss, 2000a; Lawrie & Ledward, 2006a; McAfee *et al.*, 2010).

For the last three decades the nutritional image of red meat has been under investigation and has suffered greatly as a result of several studies associating the consumption of animal fats (specifically the saturated fatty acids), to colorectal cancer, cardiovascular diseases (CVD) and other non-communicable diseases such as hypertension, obesity and metabolic syndrome (Higgs, 2000; Jiménez-Colmenero *et al*., 2001; Wood *et al.*, 2003; Biesalski, 2005; McNeill & Van Elswyk, 2012). As a result consumer preferences have changed towards favouring lean red meat. However, recent studies have emphasized the importance of distinguishing between fresh and processed meat products as the latter is known to contain more fat – a large section of the previous studies did not make this discernment (McAfee *et al*, 2010). Furthermore, it was also highlighted that no correlation were found between the consumption of unprocessed lean red meat (within the recommended dietary amounts) and coronary heart diseases in recent studies (McAfee *et al.*, 2010; McNeill & Van Elswyk, 2012; Kappeler *et al.*, 2013; Micha *et al.*, 2013; Rohrman *et al.*, 2013; Binnie *et al.*, 2014). Therefore, as part of finding strategies to improve dietary patterns in both developed and developing countries, the consumption of nutrient dense foods such as lean red meat is recommended (Binnie *et al.*, 2014).

Until very recently it was presumed that the meat quality and yield (Chapters 3 and 4) of the indigenous sheep breeds are inferior to that of the commercial meat breeds currently farmed with in South Africa (Tshabalala *et al.*, 2003). However, in rural communities in developing countries small ruminants (sheep and goats) are the livelihood of many consumers (Tshabalala *et al.*, 2003) and research has indicated that with the current trends in global weather changes tending towards drier, warmer climates, extensive livestock farmers will favour the breeds, as well as species, better adapted to the resultant changes in the ecosystems. In addition, indigenous small stock breeds, particularly those of fat-tailed nature are well adapted to surviving under harsh conditions including a low plane of nutrition – and would thus be better inclined towards delivering meat of good quality while on a low plane of nutrition, than the commercial (imported/composite) meat breeds would be.

The fat-tailed Namaqua Afrikaner is such an indigenous fat-tailed breed, doing well in a free-range farming system and well known for its ability to survive in the harsh South African climate, being nutritionally sustained on a low plane of nutrition (Epstein, 1960; Hugo, 1966; Epstein, 1971; Campbell, 1995; Ramsay *et al.,* 2001; Cloete & Olivier, 2010). Although expected to produce very lean meat as a result of storing excess fat in its fat-tail, very little information is available on the meat quality and nutritional value of the Namaqua Afrikaner's meat. This is a direct result of the Namaqua Afrikaner's fall into commercial obscurity in the early 20th century. The development of the Namaqua Afrikaner sheep has been marked by natural and to some extent, unconscious selection, hence it can be said that its meat quality has not been altered or improved through selective breeding for the enhancement of commercially important traits (Epstein, 1960; Hugo, 1966; Zohary *et al*., 1998; Buduram, 2004; Snyman *et al.*, 2013). The breed is regarded as an endangered indigenous breed being conserved in a number of flocks (Qwabe *et al*., 2013).

The Dorper is South Africa's main commercially farmed meat producing breed (Cloete & Olivier, 2010). It is considered to produce meat of good quality as a result of its development through selective breeding in favour of commercial traits including the improvement of meat quality (Webb & Casey, 1995; Brand, 2000; Milne, 2000; Ramsay *et al.,* 2001; Snowder & Duckett, 2003). However, the Dorper is an early maturing breed, growing faster and reaching the fattening phase at a younger chronological age than late maturing counterparts. As a result the Dorper can be slaughtered at a younger age, but the carcasses can present with excess fat at lower carcass weights (Cloete *et al.*, 2007).

The late maturing South African Mutton Merino (SAMM) breed is South Africa's main dual-purpose breeds, farmed for both meat and wool. Research has shown that the SAMM has a large body frame and meat of good quality (i.e. tender) with a SAMM x Dorper cross showing a reduced subcutaneous fat (SCF) depth relative to pure Dorpers (Cloete *et al.*, 2007). Being late maturing, it is expected that that the carcass and meat of this breed will contain less fat, than an early maturing breed (e.g. Dorper) if slaughtered at the same chronological age (Van der Westhuizen, 2010).

Crossbreeding through the mating of divergent breeds is used to improve possible commercial gain (Kinghorn & Atkins, 1987). Crossbred genotypes are known to express hybrid vigour (improvement of performance) and are commonly found to be more robust, with an improved lamb survival and early lamb growth, as well as a higher resistance to common stressors (Fogarty, 2006). Studies on Australian lamb have shown that intramuscular fat (IMF) content has a high heritability estimate (0.48) (Jacob & Pethick, 2014; Mortimer *et al.*, 2014). Also, research has shown that crossbreeding Dorper dams with SAMM sires results in a lower shear force value of the *longissimus thoracis et lumborum* of the crossbred genotype (Cloete *et al.,* 2007). Furthermore, the desired traits of indigenous breeds, such as being adapted to a lower plane of nutrition and resistance to external parasites, are often enhanced through crossbreeding with commercial breeds (Piedrafita *et al.*, 2010; Pannier *et al*., 2014). Therefore, it is possible that the combination of desirable traits i.e. meat quality of the Dorper and SAMM and the hardiness/leanness of the Namaqua Afrikaner will only be presented in crossbred genotypes (Pannier *et al.*, 2014).

Therefore, the aim of this study was to determine how the meat quality and proximate composition of the Namaqua Afrikaner and a NA x D crossbred genotype compares to the improved breeds (Dorper and SAMM) and their crossbred progeny (SAMM x D), the latter cross following from the study of Cloete *et al*. (2007).

5.2 Materials and methods

5.2.1 Experimental site and lamb management

The trial took place at the Nortier Research farm – the experimental site and prevalent climate conditions have been discussed in detail in Chapter 4.

The research was conducted over a three year period, running from 2010-2012. Purebred Dorper, SAMM and Namaqua Afrikaner lambs were included and by making use of Dorper ewes as dam line, terminal crossbred lambs with the Namaqua Afrikaner and SAMM sire lines were also included. An average of 200 ewes were utilised as the dam line every year. Ewes were randomly allocated to single sire mating groups, where one SAMM ram and three to four Dorper and Namaqua Afrikaner rams were used to represent each ram breed (Cloete, 2007). For the terminal crosses (SAMM x D and NA x D) roughly equal groups of ewes were assigned to each ram, but for the groups of purebred offspring (Dorper, Namaqua Afrikaner and SAMM) more ewes were assigned to meet replacement needs. After mating has taken place, all the ewes were run together in a single flock to ensure grazing on the same type of vegetation. Additional lamb management procedures are well documented in Chapter 4, with the main difference being that in the current section of the study data was collected over a three-year period, running from 2010-2012.

5.2.2 Slaughtering procedure

Lambs were weighed and selected on visual appraisal as slaughter ready. As these weights were recorded within 24 hours *ante mortem*, the same weights were used as slaughter weight. The lambs were transported approximately 250 km by truck to Roelcor Abattoir – a commercial abattoir in Malmesbury (33°27'0S; 18°41'60E). There the lambs were housed in overnight lairage, with *ad libitum* access to water, but no access to food. Slaughter procedures are well documented in Chapter 4 (subheading 4.2.3); with the main difference being that in the current section of the study data was collected over a three-year period, running from 2010-2012.

Immediately following exsanguination, the carcasses were dressed and tagged with numbered tags to simplify identification upon sample collection. Forty five minutes after exsanguination and dressing the pH (pH_{45}) and temperature ($Temp_{45}$) of each carcass was measured and the carcasses were moved into cold storage (4°C).

5.2.3 Sample preparation

After being cooled and kept in cold storage for 48 h (4°C) at the abattoir, the dressed carcasses were weighed to obtain cold carcass weight. Temperature ($Temp_u$) and the ultimate pH (pH_u) were measured and annotated. The *longissimus lumborum* (LL) muscle was excised from the first to the sixth lumbar vertebrae on both sides of each carcass, placed in coded bags and transported to the Meat Science Laboratory at the University of Stellenbosch. There the right LL were vacuum sealed and stored at -20°C for sensory analysis at a later stage (Chapter 6). The left LL was used for the analysis of the physical as well as the chemical properties of the meat. The physical analyses (subcutaneous fat depth, percentage cooking loss, percentage drip loss, colour and Warner Bratzler shear force) of each muscle sample were conducted immediately upon arrival at the Meat Science laboratory. Starting from the posterior side, two sub-samples (1.5-2.5 cm thick steaks) were cut from the LL. The remaining part of the LL was sealed in vacuum packs and stored at -20°C until the chemical (proximate) analysis could be conducted.

5.2.4 Physical measurements

5.2.4.1 pH and temperature

The pH and temperature of the *longissimus lumborum* (LL) was measured on the left side of the carcass, between the 11th and 13th rib, at ≈45 min (pH_{45}; $Temp_{45}$) as well as 48 h (pH_u; $Temp_u$) *post mortem*. Both pH and temperature measurements were taken by means of a CRISON PH 25 portable handheld pH meter (507) (Lasec (Pty) Ltd, South Africa), fitted with a glass CRISON electrode (Cat. 52-32) and equipped with an automatic thermometer, allowing for simultaneous measurements of pH and temperature. The pH meter was calibrated with the standard buffers, provided by the manufacturer, at pH 4.0 and pH 7.0.

5.2.4.2 Subcutaneous fat depth measurements

Measurements of the subcutaneous fat depth are well documented in Chapter 4 (subheading 4.2.4.2); with the main difference being that in the current section of the study the data was collected over a three-year period, running from 2010-2012.

5.2.4.3 Drip loss (%)

A sub-sample (1.5-2.5 cm thick) were cut from the left LL and weighed to the nearest gram (initial weight, W_1) (Honikel, 1998). Each sample were individually suspended from a thin piece of wire (threaded through a small hole in the sample), inside an inflated, sealed polyethylene bag. The bags were left hanging at refrigeration temperatures (4°C) for 24 h. After 24 h the meat samples were removed from the bags, lightly blotted dry with absorbent paper to remove excess moisture and weighed (final weight, W_2). Drip loss were calculated and expressed as a percentage of the initial weight of the sample, applying the following formula (Honikel, 1998):

$$\text{Drip loss (\%)} = ((W_1 - W_2) / W_1) \times 100\%$$

5.2.4.4 Cooking loss (%)

A second sub-sample (1.5-2.5 cm thick) were cut from the left LL and weighed to the nearest gram (initial weight, W_1), prior to being inserted into a coded polyethylene bag (Honikel, 1998). These samples (inside the bags) were cooked in a water bath for 60 min at 80°C. Afterwards the bags were removed, drained of all water and submersed into cold water to allow for the samples to cool down. These were left overnight at refrigeration temperatures (4°C). Following the cooling down period, the samples were removed from the bags, gently blotted dry with absorbent paper and weighed (final weight, W_2). Cooking loss were calculated and expressed as a percentage of the initial weight of the sample, applying the following formula (Honikel, 1998):

$$\text{Cooking loss (\%)} = ((W_1 - W_2) / W_1) \times 100\%$$

5.2.4.5 Colour

Evaluation of the surface colour of the meat were commenced by exposing the freshly cut sub-samples (to be used for cooking loss) to the atmosphere for 30 min, allowing time to bloom (oxygenate) (Honikel, 1998). Using a calibrated handheld Color-guide 45°/0° colorimeter (BYK-Gardner GmbH, Gerestried, Germany) three measurements were taken at random locations on the bloomed surface to determine the CIEL* (lightness), a* (green-red range) and b* (blue-yellow range) values. The Chroma (colour intensity/saturation) and hue angle (colour definition/dimension) were calculated using the a* and b* values (Honikel, 1998):

$$\text{Chroma } (C^*) = ((a^*)^2 + (b^*)^2)^{-0.5}$$

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

The colorimeter was calibrated using the green, black (L* = 0) and white (L* = 100) standards as provided.

5.2.4.6 Warner-Bratzler shear force (Instrumental tenderness)

After determination of percentage cooking loss, the cooked samples were used to evaluate the tenderness of the cooked samples using the Warner-Bratzler shear force method (Honikel, 1998). Cylindrical cores (1.27 cm diameter) were cut at random from the centre of the cooled (4°C) LL samples, parallel to the muscle fibre direction. Utilising a Warner-Bratzler shear attachment, the cores were cut perpendicular to the longitudinal axis of the muscle, recording maximum shear force (N) necessary for shearing a cylindrical core (1.27 cm ø) at a crosshead speed of 200.0 mm/min. Three cores were analysed per LL sample and the means were calculated for statistical analysis of the data.

5.2.5 Chemical analyses

Upon completion of the physical analysis, the remainder of the LL muscle (anterior part) was vacuum-packed and stored at -20°C until the chemical analysis could be conducted. Samples were defrosted for 12 h (overnight) at 4°C, all visible subcutaneous fat and sinews removed and homogenised for 30 seconds, mixed and homogenised for a further 15 seconds until a paste-like texture could be observed. Homogenised samples were scooped into a pre-weighed plastic container (W_1), evenly distributed and weighed again (sample plus container) (initial sample weight, W_2) and sealed with a tight fitting lid (not weighed), and stored at -20°C until being freeze dried.

The reason behind freezing the fresh (2012) samples and not immediately homogenising these are a result of the manner in which samples collected during the previous two years (2010, 2011) were treated during the calibration and verification of the NIR. Consequently, to minimise the possibility of an experimental error, samples collected in 2012 were treated the same.

5.2.5.1 Freeze drying

The plastic containers containing the frozen, homogenised samples were placed inside a CHRIST freeze-drier (Model 2002, MARTIN CHRIST, Germany) and freeze-dried for 72 hours. The lids of the containers were removed before freeze-drying. When removed from the freeze-drier, samples were weighed (dried sample plus container) (final/dried weight, W_3) and the lid was replaced. These weights were used in the determination of the percentage moisture content of the sample:

$$\text{Moisture content (\%)} = ((W_2 - (W_3 - W_1)) / W_2) \times 100\%$$

Samples were kept in the freezer (-20°C) until milled to obtain a fine powder, which was vacuum-packed in polyethylene bags and stored at -20°C until analysed for proximate composition through near infrared spectroscopy.

5.2.5.2 Near infrared spectroscopy (NIRS)

An average of six gram of the milled freeze-dried samples was tightly packed into a sample cup of the InfraAlyzer 500 Near Infrared Reflectance Analyser (IA-500). Making use of Bran+Luebbe SESAME Version 2.00-software (BRAN+LUEBBE GmbH, Norderstedt, Germany) the near infrared spectra of the samples were measured with the InfraAlyzer. Recordings of the measurements were made at log 1/R at 2 nm intervals while the spectra were measured over the wavelength range of 1100-2500 nm (Viljoen *et al.*, 2007).

Calibration of the InfraAlyzer were done with results obtained from performing wet chemistry on all 100 samples to contribute to the development of calibration equations as described by Viljoen *et al.* (2007). NIRS is regarded as an appropriate method for the determination of the chemical composition of meat products (Prieto *et al.*, 2009; Manley, 2014). It is treated as an appropriate alternative to the time-consuming and expensive analytical methods used in laboratories; methods which are often dangerous to human health as well as harmful to the environment (Prieto *et al*., 2009). One of the main benefits of NIRS is the speed at which results can be obtained – after calibration freeze-dried samples can be scanned and within approximately two minutes the results are generated (Viljoen *et al.*, 2007).

5.2.5.3 Wet chemistry

Wet chemistry performed on the freeze dried samples was done according to AOAC (2002) methods. Residual moisture (%) (g.100 g^{-1}) were determined according to AOAC official method 934.01, with the necessary calculations and adjustments being made to rule out the possibility of residual moisture picked-up during handling of the freeze-dried sample. The ash concentration of the moisture free sample was determined at 500°C (6 h) according to AOAC method 942.05. AOAC method 920.39 was used to determine the percentage intramuscular fat in each of the samples, while method 976.05 (AOAC, 2002) was used to determine the crude protein concentration of the meat.

5.2.6 Statistical analyses

A completely randomised design with factorial arrangement of the treatments was used with breed and production year (2010-2012) as main effects.

Model: $Y_{ijk} = \mu + \lambda + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$, where:

- Y_{ijk}: the k^{th} response to the combination of the i^{th} treatment of production year and the j^{th} treatment of breed
- μ: the overall mean
- λ: slaughter age as a covariate to correct for age differences
- α_i: the main effect of the i^{th} treatment of production year
- β_j: the main effect of the j^{th} treatment of lamb breed
- $(\alpha\beta)_{ij}$: the interaction between the i^{th} treatment of production year and the j^{th} treatment of breed
- $\varepsilon_{ij:}$ the random error corresponding to the k^{th} response to the combination of the i^{th} treatment of Factor A and the j^{th} treatment of Factor B

Analysis of covariance was performed on all variables accessed (carcass characteristics, physical attributes and chemical composition), using the GLM (General Linear Models) procedure of SAS software (Version 9.2; SAS Institute Inc., Cary, USA). The Shapiro-Wilk test was performed on the standardized residuals from the model to test for normality (Shapiro & Wilk, 1965). Outliers were removed in cases where there was significant deviation from normality. A probability level of 5% was considered significant for all significance tests. Bonferroni *post hoc* test least square means (LSM) (± SE) were calculated and used to correct for the unbalanced nature of the data. R-square Type III P-values were used to test for significant differences. All results (except pH_{45} and pH_u) were corrected with slaughter age as covariate and a significance level of 95% was used as basis for all calculations. The corresponding temperature was used as covariate for pH_{45} and pH_u.

Additionally a completely randomised design with factorial arrangement of the treatments was used with breed and birth status (single or multiple) as main effects. Analysis of variance (ANOVA) was performed on all variables accessed (carcass characteristics), using the GLM (General Linear Models) procedure of SAS software (Version 9.2; SAS Institute Inc., Cary, USA). Interpretation of data was done as discussed above.

5.3 Results

P-values for the carcass weight and characteristics and physical meat attributes are depicted in Table 5.1 for the three-year period (2010-2012), indicating whether or not an interaction between the main effects (lamb breed and production year) exists. Where interactions do exist, they will be discussed as such, if they are considered as being biologically important/significant. Results of the main effects, lamb breed (Table 5.2) and production year (Table 5.3) will be discussed where no interactions were reported.

5.3.1 Carcass characteristics

Differences between singles and multiples (twins and triplets) were observed in birth and weaning weights as well as dressing %, where single born lambs had the higher weights in all cases. As these results are in consistent with well-established trends in local and overseas research (Cloete *et al*., 1998; Cloete *et al*., 2003; Cloete *et al*., 2007; Gardner *et al*., 2007; Safari *et al*., 2007), it will thus not be discussed further.

Breed differences (P = 0.002) were observed in the birth weights of the lambs, but no differences as a result of production (lambing) year (P = 0.173) were reported (Table 5.1). No differences were observed in birth weight between the Dorper (4.2 ± 0.07 kg), SAMM (4.4 ± 0.20 kg), NA x D (4.2 ± 0.13 kg) and SAMM x D (4.4 ± 0.17 kg; P > 0.05) lambs (Table 5.2). The Namaqua Afrikaner (3.8 ± 0.12; P = 0.002) had the lowest birth weight in absolute terms, however it did not differ (P > 0.05) from the birth weights of the other purebred SAMM and Dorper lambs (Table 5.2). With weaning weight the results were surprisingly different, breed and year differences were observed (P < 0.001) (Table 5.1) – the mean weaning weight of the Namaqua Afrikaner (23.5 ± 0.49 kg; P < 0.001) were substantially less than those of all the other breeds/crosses, while these did not differ from each other (P > 0.05) (Table 5.2). The mean weaning weight of 2012 lambs (27.9 ± 0.94) was also less than in 2010 (32.3 ± 0.80) and 2011 (33.6 ± 0.78; P < 0.001) (Table 5.1).

5.3.1.1 Slaughter weight, carcass weight and dressing percentage

Upon analysis of the results it was established that growth and carcass characteristics were influenced by breed, but differences attributable to production year were only seen with dressing % (P = 0.027) (Table 5.1). The only breed that had a different slaughter (live) weight in comparison with the other pure breeds/crosses was the fat-tailed Namaqua Afrikaner with a lighter live weight of 30.2 ± 0.71 kg (P < 0.001) (Table 5.2). The SAMM x D cross had the heaviest live weight in absolute terms at 40.4 ± 1.10 kg, but no differences in live weight were recorded with the Dorper, SAMM, and NA x D, weighing 37.3 ± 0.45 kg, 38.0 ± 1.27 kg and 37.7 ± 0.84 kg, respectively (Table 5.2). Similar results were obtained with regard to cold carcass weight. The Namaqua Afrikaner carcasses (11.0 ± 0.43 kg) were the lightest, while the SAMM x D cross weighed the heaviest in absolute terms (18.0 ± 0.68 kg; P < 0.001) (Table 5.2). The Dorper (16.3 ± 0.29 kg), SAMM (15.3 ± 0.80 kg) and NA x D cross (16.4 ± 0.51 kg) carcasses were heavier than the Namaqua Afrikaner, but did not differ from the SAMM x D cross (P > 0.05) (Table 5.2).

Results for dressing percentage are similar, with the SAMM x D (45.3 ± 1.13 %), attaining the highest dressing percentage, while the Namaqua Afrikaner's dressing percentage were the lowest (36.4 ± 0.75 %; P < 0.001) in absolute terms. The dressing percentage of the Dorper (43.2 ± 0.48

%) and NA x D (43.5 ±0.87 %) were intermediate and only different ($P \leq 0.05$) from the SAMM x D (Table 5.2). The SAMM (39.9 ± 1.36 %) only differed from the SAMM x D (Table 5.2). Differences in production year were recorded, with the overall dressing percentage in 2011 (40.7 ± 0.73 %) being the lowest and the highest in 2012 (43.0 ± 0.86 kg), while 2010 was intermediate and did not differ from either 2011 or 2012 (Table 5.3).

5.3.2 Physical attributes

5.3.2.1 pH and temperature

Breed differences were observed in the pH_{45} results ($P = 0.038$) (Table 5.1). The NA x D cross (7.06 ± 0.05) had the highest pH_{45} and the SAMM (6.71 ± 0.07 ± 0.07) the lowest in absolute terms (Table 5.2). The result of the Dorper (6.85 ± 0.03; $P \leq 0.05$) only differed from that of the NA x D, while the SAMM x D (7.00 ± 0.06) only differed from the SAMM (Table 5.2). An interesting observation was that the unimproved and "flighty" natured Namaqua Afrikaner's pH_{45} (6.89 ± 0.04) were regarded as intermediate as it did not differ from any of the pure breeds or the crossbred genotypes ($P > 0.05$) (Table 5.1).

Breed differences ($P < 0.001$) were seen in the ultimate pH of the meat (Table 5.1), with the purebred SAMM meat at the highest pH_u of 5.86 ± 0.04 in absolute terms (Table 5.2). Both the other pure breeds had pH_u readings similar to that of the SAMM – Dorper meat had a pH_u of 5.75 ± 0.01 and the Namaqua Afrikaner a pH_u of 5.82 ± 0.02. The crossbred genotypes were both able to attain a lower ($P < 0.001$) pH_u of 5.66 ± 0.03 and 5.69 ± 0.03 for NA x D and SAMM x D, respectively (Table 5.2).

In addition, pH_u were divided into categories (Table 5.4) and investigated as such, also with the main effect of breed. In this instance the majority of the pH_u of the Namaqua Afrikaner (53%) and SAMM (65%) carcasses were ≥ 5.81, while the majority of Dorper (74%), NA x D (88%) and SAMM x D (83%) carcasses fell into the pH_u-category below 5.81 ($P > 0.001$) (Tables 5.1 & 5.2). Temperature ($Temp_{45}$ and $Temp_u$ for pH_{45} and pH_u respectively) was used as a covariate to correct main effect means, as it is known that carcass temperature will affect the pH value of the meat (Busch *et al.*, 1967; Bruce & Ball, 1990).

5.3.2.2 Subcutaneous fat (SCF) depth and tail fat

As expected, lamb breed as a main effect had a strong ($P < 0.001$) influence on the SCF (Table 5.1). Measured at both the 13th rib and the 3rd/4th lumbar vertebrae, breed differences were observed ($P < 0.001$), while no differences were seen as a result of production year (measured at both the 13th rib and the 3rd/4th lumbar vertebrae: $P = 0.423$ and $P = 0.946$ respectively) (Table 5.1). The interaction between the two main effects was also not significant for either of the sites measured ($P = 0.689$; $P = 0.584$ respectively) (Table 5.1).

Measured at the 13th rib, the SCF cover of the NA x D cross were the thickest ($P < 0.001$) at 2.4 ± 0.27 mm, while the SCF cover of the Namaqua Afrikaner and SAMM only measured 0.6 ±

0.21 mm and 0.7 ± 0.38 mm, respectively (Table 5.2); the SCF of the latter two breeds being similar. The SCF depth of the crossbred genotype, NA x D did not differ from that of the Dorper (2.1 ± 0.14 mm), while the SAMM x D cross (1.8 ± 0.32 mm) were intermediate and did not show differences from either the fatter purebred Dorper and crossbred NA x D or leaner purebred SAMM ($P > 0.05$) (Table 5.2). When measured at the 3rd/4th lumbar vertebrae the SCF depth of the Dorper (5.1 ± 0.27 mm), NA x D (5.4 ± 0.51 mm) and SAMM x D (4.8 ± 0.61 mm) were similar, but differed ($P < 0.001$) from the SCF depth of the Namaqua Afrikaner (2.5 ± 0.39 mm) and the SAMM (1.5 ± 0.72 mm) (Table 5.2).

5.3.2.3 Drip loss (%) and cooking loss (%)

Lamb breed interacted ($P < 0.001$) with lambing year for drip loss. However, it was evident that no differences in drip loss among lamb breeds were present in 2011 (1.4 ± 0.06) and 2012 (1.5 ± 0.07; $P > 0.05$) (Table 5.3) and that the differences responsible for the interaction were confined to 2010. At 3.1 ± 0.12% during 2010, the drip loss of Namaqua Afrikaner lambs were about double the corresponding overall means for all lambs in 2011 and 2012 (Table 5.6). Means for the Dorper and NA x D cross in 2010 were also higher than most other year-breed means at respectively 2.2 ± 0.14% and 2.1 ± 0.06% drip loss (Table 5.5).

Although no interaction was observed, both lamb breed ($P < 0.001$) and production year ($P < 0.001$) had an influence on the total percentage cooking loss (Table 5.1). The meat samples of the pure SAMM (30.9 ± 0.92%) showed a higher ($P < 0.001$) percentage cooking loss than all of the other samples of the different breeds/crosses; Dorper (27.2 ± 0.35%), Namaqua Afrikaner (27.5 ± 0.50%), NA x D (25.7 ± 0.65%) and the SAMM x D (27.4 ± 0.78%) (Table 5.2). No differences were observed between latter lamb breeds ($P > 0.05$). Also, the overall percentage cooking loss of samples collected during 2010 (32.6 ± 0.50%) were higher than those collected in 2011 (27.5 ± 0.50%; $P < 0.001$) which in turn were higher than those collected in 2012 (23.2 ± 0.55% $P < 0.001$) (Table 5.3).

5.3.2.4 Colour

Interactions between lamb breed and production year were observed for the L* (lightness) ($P = 0.004$), a* (redness) ($P = 0.045$) and hue values ($P = 0.006$) (Table 5.1). For the b* and Chroma values an interaction between the main effects were not observed ($P = 0.171$ and $P = 0.157$, respectively), nor any differences as a result of lamb breed ($P = 0.312$ and $P = 0.405$, respectively). However, differences in production year were observed in the Chroma value ($P < 0.001$), with 2012 (16.9 ± 0.28) being higher compared to 2010 (14.7 ± 0.25) and 2011 (15.3 ± 0.26) (Table 5.3).

When the results of the interaction between the main effects are investigated for L* and a* values, an interesting observation was made (Table 5.5). Although an interaction was seen between lamb breed and production year, only two breeds from two different years (Dorper; 2010 and NA x D; 2012) differed from each other, while all the other groups of breeds/crosses over the three year period did not differ from each other (P > 0.05) (Table 5.5). A similar observation was made for the a* value – although there were breeds similar to one another in different years, the majority of the sample groups within a year group were similar to each other, while differing from the other years. It can be argued that the majority of the differences were rather as a result of different production years than true breed differences. Therefore, even though the interaction is statistically significant (P ≤ 0.05) (Table 5.1), since such a clear trend is visible it makes more sense from a biological viewpoint to discuss the main effects separately (Tables 5.2 & 5.3).

When viewing breed differences, only the L* value indicated differences (P < 0.001) in the lightness of the meat of the different breeds/crosses. The meat of the SAMM (39.0 ± 0.43), together with that of the Namaqua Afrikaner (38.4 ± 0.23) and SAMM x D (37.8 ± 0.37) were the lightest colour, whereas the Dorper's (36.8 ± 0.16) meat was the darkest in absolute terms, but only significantly darker that the meat from SAMM and Namaqua Afrikaner lambs (P ≤ 0.05). The meat of the Namaqua Afrikaner (38.4 ± 0.23) was intermediate and only differed from the Dorper. The L* value of the SAMM x D cross meat were similar to that of all the other breeds (Table 5.2). No breed differences were observed for the a* (P = 0.483) and hue values (P = 0.408) (Table 5.1).

No breed differences were observed in any of the other colour parameters measured, but a*, hue and Chroma were influenced by production year. The a* value of 2012 was the highest (14.0 ± 0.24) and the mean for 2010 (11.1± 0.23; P < 0.001) the lowest. The value of 2011 (12.1 ± 0.23) was intermediate and did not differ from either year (P > 0.05) (Table 5.3). Samples of 2012 (34.2 ± 0.55) had the lowest hue values, while those from 2010 (41.0 ± 0.50) had the highest value; 2011 (37.2 ± 0.52) had values that differed from both years (P < 0.001) (Table 5.3). Chroma values were the same for 2010 (14.7 ± 0.25) and 2011 (15.3 ± 0.26) while different from that of 2012 (16.9 ± 0.28; P < 0.001).

5.3.2.5 Warner-Bratzler shear force (Instrumental tenderness)

Interestingly, no differences in shear force were observed as a result of breed (P = 0.081). Neither were an interaction observed between the main effects (P = 0.149). However, differences as a result of production year were observed (P < 0.001). The shear force of the cooked meat samples from 2011 (60.0 ± 1.72) were measured as significantly higher (less tender) than that of 2010 (46.9 ± 1.70) and (43.1 ± 1.88).

Table 5.1 P-values for the main effects of lamb breed and production year as well as the two-way interaction between these main effects for carcass characteristics and physical attributes of the *longissimus lumborum* muscle

Attributes and characteristics	**Breed**	**Year**	**Breed x year interaction**
Birth weight (kg)	0.002	0.173	-
Weaning weight (kg)	<.001	<.001	-
Slaughter (live) weight (kg)	<.001	0.714	-
Carcass weight (kg)	<.001	0.318	-
Dressing %	<.001	0.027	-
pH_{45}	0.038	-	-
pH_u	<.001	-	-
$pH_{category}$	<.001	-	-
SCF thickness: 13th rib (mm)	<.001	0.423	0.689
SCF thickness: 3rd/4th lumbar vertebrae (mm)	<.001	0.946	0.584
Drip loss (%)	<.001	<.001	<.001
Cooking loss (%)	<.001	<.001	0.765
Shear force (Warner-Bratzler) (N)	0.081	<.001	0.149
L*	<.001	0.036	0.004
a*	0.483	<.001	0.045
b*	0.312	0.287	0.171
Chroma	0.405	<.001	0.157
Hue	0.408	<.001	0.006

Table 5.2 Least square means (± SE) depicting the main effect of lamb breed on carcass characteristics and physical attributes

Carcass characteristic	**Dorper**	**Namaqua Afrikaner**	**NA x D^1**	**SAMM^2**	**SAMM x D^3**
Birth weight (kg)	4.1^{ab} ± 0.07	3.8^{b} ± 0.11	4.2^{a} ± 0.13	4.4^{ab} ± 0.20	4.4^{a} ± 0.17
Weaning weight (kg)	32.4^{a} ± 0.56	23.5^{b} ± 0.49	33.7^{a} ± 1.30	31.6^{a} ± 1.34	37.3^{a} ± 1.20
Slaughter (live) weight (kg)	37.3^{a} ± 0.45	30.2^{b} ± 0.71	37.7^{a} ± 0.84	38.0^{a} ± 1.27	40.4^{a} ± 1.10
Carcass weight (kg)*	16.3^{a} ± 0.29	11.0^{b} ± 0.43	16.4^{a} ± 0.51	15.3^{a} ± 0.80	18.0^{a} ± 0.68
Dressing %	43.2^{ab} ±0.48	36.4^{b} ± 0.75	43.5^{ab} ± 0.87	39.9^{b} ± 1.36	45.3^{a} ± 1.13
pH$_{45}$	6.85^{bc} ± 0.03	6.89^{abc} ± 0.04	7.03^{a} ± 0.05	6.70^{c} ± 0.06	7.00^{ab} ± 0.06
pH$_{u}$	5.75^{ab} ± 0.01	5.82^{a} ± 0.02	5.66^{b} ± 0.03	5.86^{a} ± 0.04	5.69^{b} ± 0.03
pH$_{category}$	5.7^{b} ± 0.01	5.7^{a} ± 0.02	5.6^{b} ± 0.02	5.8^{a} ± 0.03	5.6^{b} ± 0.02
SCF thickness: 13th rib (mm)	2.1^{a} ± 0.14	0.6^{c} ± 0.21	2.4^{a} ± 0.27	0.7^{bc} ± 0.38	1.8^{ab} ± 0.32
SCF thickness: 3rd/4th lumbar vertebrae (mm)	5.1^{a} ± 0.27	2.5^{b} ± 0.39	5.4^{a} ± 0.51	1.5^{b} ± 0.72	4.8^{a} ± 0.61
Drip loss (%)#	1.7^{b} ± 0.04	2.0^{a} ± 0.06	1.6^{b} ± 0.08	1.8^{ab} ± 0.11	1.5^{b} ± 0.10
Cooking loss (%)	27.2^{b} ± 0.35	27.5^{b} ± 0.50	25.7^{b} ± 0.65	30.9^{a} ± 0.92	27.4^{b} ± 0.78
Shear force (Warner-Bratzler) (N)	48.9 ± 1.19	53.1 ± 1.73	48.7 ± 2.21	53.7 ± 3.13	45.6 ± 2.64
L*#	36.8^{c} ± 0.16	38.4^{ab} ± 0.23	37.5^{bc} ± 0.30	39.0^{a} ± 0.43	37.8^{ac} ± 0.37
a*#	12.6 ± 0.15	12.1 ± 0.22	12.3 ± 0.2	12.3 ± 0.41	12.5 ± 0.35
b*	9.5 ± 0.12	9.4 ± 0.18	9.4 ± 0.23	9.8 ± 0.33	9.2 ± 0.29
Chroma	15.9 ± 0.17	15.2 ± 0.25	15.6 ± 0.33	15.8 ± 0.46	15.6 ±0.40
Hue#	37.1 ± 0.35	37.1 ± 0.50	37.8 ± 0.65	38.8 ± 0.92	36.7 ± 0.80

SE = Standard Error;
[1] NA x D = Namaqua Afrikaner x Dorper cross;
[2] SAMM = South African Mutton Merino;
[3] SAMM x D= South African Mutton Merino x Dorper cross;
[abc] Means in the same row with different superscripts are significantly different ($P \leq 0.05$);
Interaction between lamb breed and production year.

Table 5.3 Least square means (± SE) depicting the main effect of production year on the comparison of carcass characteristics and physical attributes where significant

Carcass characteristic	**2010**	**2011**	**2012**
Weaning weight (kg)	32.3^{a} ± 0.80	33.6^{a} ± 0.78	27.9^{b} ± 0.94
Dressing %	42.3^{ab} ± 0.79	40.7^{b} ± 0.73	43.0^{a} ± 0.86
Drip loss (%)#	2.2^{a} ± 0.06	1.4^{b} ± 0.06	1.5^{b} ± 0.07
Cooking loss (%)	32.6^{a} ± 0.50	27.5^{b} ± 0.50	23.2^{c} ± 0.55
Shear force (Warner-Bratzler) (N)	46.9^{a} ± 1.70	60.0^{b} ± 1.72	43.1^{a} ± 1.88
a*#	11.1^{b}± 0.23	12.1^{ab} ± 0.23	14.0^{a} ± 0.24
Chroma	14.7^{b} ± 0.25	15.3^{b} ± 0.26	16.9^{a} ± 0.28
Hue#	41.0^{a} ± 0.50	37.2^{b} ± 0.52	34.2^{c} ± 0.55

SE = Standard Error;
[abc] Means in the same row with different superscripts are significantly different ($P \leq 0.05$);
Interaction between lamb breed and production year.

Table 5.4 Number (%) of carcasses per breed when categorised according to the ultimate pH of the *longissimus lumborum* muscle

Breed	**pH category**				
	pH ≤ 5.60	**5.61 < pH ≤ 5.80**	**5.81 < pH ≤ 6.00**	**6.01 < pH ≤ 6.2**	**6.2 < pH**
Dorper (n = 163)	13 (8)	107 (66)	39 (24)	2 (1)	2 (1)
Namaqua Afrikaner (n = 66)	5 (8)	26 (39)	25 (38)	8 (12)	2 (3)
N x D[1] (n = 41)	12 (29)	24 (59)	4 (10)	1 (2)	0 (0)
SAMM[2] (n = 20)	1(5)	6 (30)	11 (55)	1 (5)	1 (5)
SAMM x D[3] (n = 29)	5 (17)	19 (66)	4 (14)	0 (0)	1 (3)
Total (n = 319)	**36 (11)**	**182 (57)**	**83 (26)**	**12 (4)**	**6 (2)**

[1] NA x D = Namaqua Afrikaner x Dorper cross;
[2] SAMM = South African Mutton Merino;
[3] SAMM x D= South African Mutton Merino x Dorper cross.

Table 5.5 Least square means (± SE) depicting the two-way interaction between the main effects of breed of lamb and production year for percentage drip loss as well as the appropriate colour measurements of the *longissimus lumborum* muscle

Year	Breed	Drip loss (%)	L*	a*	Hue[#]
2010	Dorper	2.1^{b} ± 0.06	36.4^{b} ± 0.21	10.8^{d} ± 0.20	40.7^{abcd} ± 0.46
	Namaqua Afrikaner	3.0^{a} ± 0.12	37.3^{bc} ± 0.44	10.9^{d} ± 0.41	39.3^{abcde} ± 0.94
	NA x D[1]	2.2^{bc} ± 0.14	37.0^{bc} ± 0.53	10.7^{d} ± 0.50	42.0^{a} ± 1.15
	SAMM[2]	1.8^{bd} ± 0.20	39.2^{ab} ± 0.75	12.0^{ad} ± 0.71	41.3^{abc} ± 1.62
	SAMM x D[3]	1.7^{bd} ± 0.14	37.6^{bc} ± 0.51	11.0^{c} ± 0.49	41.8^{ab} ± 1.11
2011	Dorper	1.5^{d} ± 0.08	36.8^{bc} ± 0.31	12.4^{b} ± 0.29	37.5^{abcde} ± 0.66
	Namaqua Afrikaner	1.3^{d} ± 0.10	37.7^{bc} ± 0.39	12.3^{b} ± 0.37	35.5^{cde} ± 0.84
	NA x D[1]	1.4^{d} ± 0.14	36.7^{bc} ± 0.51	12.6^{bcd} ± 0.48	37.1^{abcde} ± 1.10
	SAMM[2]	1.6^{bd} ± 0.19	38.9^{ab} ± 0.70	11.0^{cd} ± 0.66	40.6^{abcd} ± 1.51
	SAMM x D[3]	1.4^{d} ± 0.16	38.5^{ab} ± 0.65	12.2^{b} ± 0.62	35.5^{bcde} ± 1.10
2012	Dorper	1.4^{d} ± 0.08	37.0^{bc} ± 0.29	14.7^{a} ± 0.27	33.3^{e} ± 0.62
	Namaqua Afrikaner	1.5^{d} ± 0.10	40.2^{bc} ± 0.38	13.2^{ac} ± 0.36	36.5^{bcde} ± 0.82
	NA x D[1]	1.3^{d} ± 0.14	38.7^{ac} ± 0.51	13.7^{ad} ± 0.49	34.2^{de} ± 1.11
	SAMM[2]	1.9^{bd} ± 0.20	38.9^{ab} ± 0.75	14.0^{ac} ± 0.71	34.4^{cde} ± 1.63
	SAMM x D[3]	1.4^{cd} ± 0.20	37.2^{ab} ± 0.75	14.4^{abd} ± 0.71	32.7^{e} ± 1.62

SE = Standard Error;

[1] NA x D = Namaqua Afrikaner x Dorper cross;

[2] SAMM = South African Mutton Merino;

[3] SAMM x D= South African Mutton Merino x Dorper cross;

[abcde] Means in the same column with different superscripts are significantly different (P ≤ 0.05);

[#] The LINES display does not reflect all significant comparisons. The following additional pairs are significantly different as well: (5,12) (1,6) (1,12) (1,7) (1,14) (1,13) (2,11) (6,11).

5.3.3 Proximate composition

Moisture (P = 0.064) and ash (P = 0.684) concentrations were independent of two way interactions between lamb breed and production year (Table 5.6). Moisture content (%) was affected by both main effects, namely lamb breed and production year respectively (P < 0. 001 for both) (Table 5.6). No breed differences were observed for ash content (%) (P = 0.302), but differences as a result of production year were observed (P = 0.002). On the other hand, significant interactions between breed and year were observed for both percentage protein (P < 0.001) and fat content (P = 0.050) (Table 5.6).

Samples from the three purebred lamb breeds, Dorper (75.2 ± 0.09%), Namaqua Afrikaner (75.5 ± 0.13%) and SAMM (75.3 ± 0.24%) contained the highest percentage moisture, while the lowest moisture content was recorded for the SAMM x D (74.2 ± 0.20%; P < 0.001) (Table 5.7).

The mean for the NA x D (74.5 ± 0.16%) was intermediate and did not differ from those of pure SAMM or the SAMM x D cross lambs ($P > 0.05$) (Table 5.7)

In 2011 (75.7 ± 0.13%) measurements of the proximate composition of the meat indicated higher moisture content (%), with 2010 (74.0 ± 0.13%) in contrast recording the lowest content; the 2012 (75.1 ± 0.14%) value was intermediate, but different from both other years (all $P \leq 0.05$) (Table 5.7). Statistically significant differences among years for ash content were too small to be of biological importance ($P < 0.05$) (Table 5.8). Therefore this will not be discussed.

When assessing the differences in the interaction between lamb breed and production year for protein content (%), it is clear that no differences ($P > 0.05$) were observed between any of the breeds within the 2011 and 2012 lambing years (Table 5.9), whereas overall means for these years also did not differ (Table 5.8). Furthermore, the mean protein content of SAMM lambs for 2010 also did not differ from any of the 2011 and 2012 samples. In 2010 however, Namaqua Afrikaner lambs had an arguably higher protein content compared to Dorper lambs (respectively 22.8 ± 0.23% vs. 21.3 ± 0.09%; $P < 0.001$) (Table 5.10). In addition the Dorper also differed from the NA x D ($P < 0.001$) and the SAMM x D ($P < 0.001$). The protein content of Namaqua Afrikaner lambs slaughtered in 2010 did not differ from late maturing SAMM lambs ($P = 0.209$) or lambs from both terminal crosses, NA x D ($P = 1.00$) or SAMM x D ($P = 1.00$).

The interaction between the main effects for fat content of the LL muscle were not as easily resolved as seen for percentage protein content (Table 5.9). However, a trend that was clear was the lower IMF content (%) of the Namaqua Afrikaner over the three years, reaching significance compared to all other breeds in 2010 ($P < 0.05$) and from the SAMM x Dorper cross in 2011 (Table 5.9). However, although no breed differences in IMF were found in 2012, the Namaqua Afrikaner carcasses still had the lowest IMF content in absolute terms. Another interesting observation was that in 2011 when the lambs were nutritionally stressed, the late maturing SAMM also had a very low IMF content (%) similar to the Namaqua Afrikaner, while in 2010 and 2012 when nutritional stressors were less, SAMM lambs developed an IMF depot comparable to the early maturing Dorper (Table 5.7).

Table 5.6 P-values for the main effects of lamb breed and production year, as well as their two-way interaction for proximate composition of the *longissimus lumborum* muscle

Proximate composition	**Breed**	**Year**	**Breed x year interaction**
Moisture (%)	<.001	<.001	0.064
Protein (%)	<.001	<.001	<.001
Fat (%)	<.001	<.001	0.050
Ash (%)	0.302	0.002	0.684

Table 5.7 Least square means (± SE) depicting the effect of lamb breed on the moisture, protein, fat and ash contents (%) of the *longissimus lumborum* muscle

Proximate composition	**Dorper**	**Namaqua Afrikaner**	**NA x D[1]**	**SAMM[2]**	**SAMM x D[3]**
Moisture (%)	75.2^{a} ± 0.09	75.5^{a} ± 0.13	74.5^{bc} ± 0.16	75.3^{ab} ± 0.24	74.2^{c} ± 0.20
Protein (%)[#]	21.0^{bc} ± 0.07	21.3^{abc} ± 0.11	21.6^{a} ± 0.13	20.7^{c} ± 0.19	21.5^{ab} ± 0.16
Fat (%)[#]	2.2^{b} ± 0.05	1.7^{c} ± 0.08	2.4^{b} ± 0.09	2.2^{b} ± 0.13	2.8^{a} ± 0.11
Ash (%)	1.2 ± 0.00	1.2 ± 0.01	1.2 ± 0.01	1.2 ± 0.01	1.2 ±0.01

SE = Standard Error;
[1] NA x D = Namaqua Afrikaner x Dorper cross;
[2] SAMM = South African Mutton Merino;
[3] SAMM x D= South African Mutton Merino x Dorper cross;
[abc] Means in the same row with different superscripts are significantly different (P ≤ 0.05);
[#] Interaction between lamb breed and production year.

Table 5.8 Least square means (± SE) depicting the effect of slaughter year on the proximate content (%) of the *longissimus lumborum* muscle

Proximate composition	**2010**	**2011**	**2012**
Moisture (%)	74.0^{c} ± 0.13	75.7^{a} ± 0.13	75.1^{b} ± 0.14
Protein (%)[#]	22.1^{a} ± 0.11	20.6^{b} ± 0.11	20.9^{b} ± 0.11
Fat (%)[#]	2.5^{a} ± 0.08	2.0^{c} ± 0.07	2.2^{b} ± 0.08
Ash (%)	1.2^{a} ± 0.00	1.2^{b} ± 0.01	1.2^{b} ± 0.01

SE = Standard Error;
[abc] Means in the same row with different superscripts are significantly different (P ≤ 0.05)
[#] Interaction between lamb breed and production year.

Table 5.9 Least square means (± SE) for the two-way interaction between breed of lamb and production year for the protein and fat contents (%) of the *longissimus lumborum* muscle

Year	Breed	Protein (%)[#]	Fat (%)
2010	Dorper	21.3^{bc} ± 0.09	2.3^{abc} ± 0.07
	Namaqua Afrikaner	22.8^{a} ± 0.23	1.6^{d} ± 0.16
	NA x D[1]	22.6^{ab} ± 0.23	2.7^{abc} ± 0.16
	SAMM[2]	21.5^{abc} ± 0.36	2.8^{ab} ± 0.25
	SAMM x D[3]	22.5^{ab} ± 0.24	3.3^{a} ± 0.17
2011	Dorper	20.8^{c} ± 0.14	2.0^{bcd} ± 0.10
	Namaqua Afrikaner	20.4^{c} ± 0.18	1.5^{d} ± 0.12
	NA x D[1]	20.9^{c} ± 0.23	2.2^{bcd} ± 0.16
	SAMM[2]	20.0^{c} ± 0.31	1.6^{cd} ± 0.22
	SAMM x D[3]	20.8^{c} ± 0.26	2.5^{abc} ± 0.18
2012	Dorper	20.9^{c} ± 0.13	2.1^{bcd} ± 0.09
	Namaqua Afrikaner	20.6^{c} ± 0.16	1.9^{bcd} ± 0.11
	NA x D[1]	21.2^{c} ± 0.22	2.3^{bcd} ± 0.15
	SAMM[2]	20.7^{c} ± 0.33	2.3^{abcd} ± 0.23
	SAMM x D[3]	21.2^{bc} ± 0.33	2.7^{abc} ± 0.23

SE = Standard Error;
[1] NA x D = Namaqua Afrikaner x Dorper cross;
[2] SAMM = South African Mutton Merino;
[3] SAMM x D= South African Mutton Merino x Dorper cross;
[abcd] Means in the same column with different superscripts are significantly different (P ≤ 0.05);
[#] The LINES display does not reflect all significant comparisons. The following additional pairs are significantly different: (3,1) (5,1) (1,12) (1,7) (1,9).

5.4 Discussion

5.4.1 Carcass characteristics

Although anecdotal data is always available, almost no scientific information with regard to the meat quality of the indigenous fat-tailed Namaqua Afrikaner could be found in published literature. Nevertheless, similar studies were conducted on sheep breeds indigenous to Iran, namely the fat-tailed Chall and thin-tailed Zel breeds (Kashan *et al.*, 2005; Yousefi *et al.*, 2012). These studies provided background to the present study.

Preliminary results indicated that the influence of birth status was as expected and agree with information found in literature (Cloete *et al*., 1998; Cloete *et al*., 2003; Cloete *et al*., 2007; Gardner *et al*., 2007; Safari *et al*., 2007). The unimproved and late maturing nature of the Namaqua Afrikaner can be argued here as the driver behind the lighter lambs, when compared to the Dorper and SAMM x D breed – smaller sheep are known to have smaller lambs and *vice versa*.

The unimproved nature of the Namaqua Afrikaner can be argued as the reason for the breed differences in weaning weight as seen between the Namaqua Afrikaner and the crossbred genotypes ($P < 0.001$) (Table 5.1). Hybrid vigour or heterosis is expected from crossbred genotypes, with a 10-40% increase in the weight of lamb weaned (Fogarty, 2006). In addition the Namaqua Afrikaner (105.6 ± 1.81 days) and SAMM (104.5 ± 3.90 days) lambs were on average 13 days younger that the Dorper (118.1 ± 1.52 days) and SAMM x D (118.1 ± 2.50 days) at weaning and almost 22 days younger than the NA x D (127.0 ± 5.21 days). Although not to be regarded a significant difference in general; but taking into account the late maturing nature of the Namaqua Afrikaner, its lighter weaning weight was expected (Table 5.2). These arguments could possibly be substantiated by the moderate Pearson correlations (r) observed between weaning weight and slaughter weight ($r = 0.683$; $P < 0.001$); as well as between weaning weight and dressing % ($r = 0.694$; $P < 0.001$). In addition, a strong correlation between weaning weight and carcass weight was reported ($r = 0.861$; $P < 0.001$). The possible reason for the differences seen in production year is a direct result of the lambs being weaned an average of 20 days earlier in 2012 compared to 2010 and 2011.

In contrast to the results of the present study, Yousefi *et al*. (2012) did not report breed differences for either slaughter or carcass weight in his study of the fat-tailed Chall and thin-tailed Zel lambs. However, Tshabalala *et al*. (2003) did report a difference in carcass weight when the Dorper was compared to another South African fat-tailed breed i.e. the Damara, with the Dorper being the heavier. This result was expected, seeing that unimproved, fat-tailed, indigenous breeds like the Damara and the Namaqua Afrikaner are expected to perform worse in terms of growth than commercial breeds that have been subjected to selection for growth and carcass characteristics.

The most plausible explanation for the results of the present study can be found in the younger physiological slaughter age of the Namaqua Afrikaner lambs (147.1 ± 1.75 days). While the SAMM (143.3 ± 3.19 days) and SAMM x D (146.0 ± 2.53 days) were slaughtered at similar chronological ages to the Namaqua Afrikaner, the unimproved nature of the latter breed are the likely cause of these differences. Being at a younger physiological age, while not improved through selective breeding for enhancement of production, at this young age (147.1 ± 1.75 days) the meat yield of the Namaqua Afrikaner will be significantly less than both pure commercial breeds, which have been selected for growth performance (Chapter 3; Burger *et al.*, 2013).

In general differences in the physiological age of the animals can be explained by the differences in the growth rates of the same carcass tissues of different breeds/species (Irshad *et al*., 2012). All animals do not grow and develop at the same rate and as a result do not reach physiological maturity at the same chronological age (Pállson, 1955; Beitz, 1985; Warriss, 2000b; Irshad *et al.*, 2012). Four stages in the growth and development of an animal's bodily tissues have been identified according to ascending rank; i.e. central nervous system; bone; muscle and fat (Pállson, 1955; Lawrie & Ledward, 2006b). These stages start simultaneously at conception and progress continuously, albeit at different rates, until physiological maturity is reached. Rates of progression are determined by the importance of the specific tissue to the survival of the animal (explained in detail in Chapters 2 & 4) (Pállson, 1955; Butterfield, 1988a; Warriss, 2000b). Among the three major tissues (muscle, fat, bone), muscle has the highest growth rate from birth to maturity, when the ratio of muscle to carcass weight will begin to decrease, whereas the ratio of fat tissue to carcass weight will increase as the fattening phase sets in (Berg & Butterflied, 1968; Butterfield, 1988a). Not only do different tissues grow and develop at different rates; within species different breeds will also reach physiological maturity at different chronological ages (Warriss, 2000b; Lawrie & Ledward, 2006b; Irshad *et al.*, 2012). The entire development cycle of an early maturing breed will take place and reach conclusion within a shorter chronological time span than will be the case with a late(r) maturing breed (Pállson, 1955; Lawrie & Ledward, 2006b). Thus it can be said that an early maturing breed will start to develop fat deposits at a younger chronological age and will therefore also be slaughter ready at a younger chronological age than its later maturing counterparts. According to results reported by Cloete *et al.* (2007), crossbreeding may allow the crossbred progeny of early-maturing and adapted Dorper ewes to be grown out to heavier slaughter weights when compared to purebred progeny, without being downgraded because of excessive fat cover (Cloete *et al*., 2007). This only partially agrees with the results of the present study as the slaughter weights of the Dorper crossbred progeny (NA x D and SAMM x D) were reported to be heavier only to that of the Namaqua Afrikaner (Table 5.2).

Also, the fat-tail of the Namaqua Afrikaner can be regarded as part of the reason for the lower dressing percentage as a substantial weight is lost when the tail is removed (Almeida *et al.*, 2013). The tails of the Namaqua Afrikaner lambs weighed about 500 g, as opposed to less than 100 g in the other pure breeds. In South Africa, abattoirs tend to downgrade fat tailed carcasses due to a lower lean yield, as fat-tails are trimmed off the warm carcass before the cold carcass weight is recorded. If the tail is trimmed on a warm carcass, this trimming is not visible when chilled (anecdotal evidence). Notwithstanding this, an interesting observation was made in the fact that the dressing percentage, after trimming off the fat-tail, of the Namaqua Afrikaner was similar to that of the improved SAMM breed (Table 5.2). The skins of the wool-bearing SAMM are expected to be heavier compared to the other breeds, thus contributing to the lower than expected dressing percentage of this breed (Cloete *et al.*, 2012).

5.4.2 Physical attributes

5.4.2.1 pH

Most notable in the pH_{45} and pH_u results is that, while the NA x D carcasses had the highest pH_{45} in absolute terms ($P = 0.038$), this breed combination also attained the lowest pH_u ($P < 0.001$) (Table 5.2). Additionally, it is important to note that, while the SAMM x D also had a high pH_{45} (7.00 ± 0.07), which was similar to that of the pure breeds and the NA x D, the SAMM x D also attained a significantly lower pH_u (5.69 ± 0.04), similar to that of the NA x D (Table 5.2). Both the pH_{45} and pH_u of the Namaqua Afrikaner were regarded as high. In addition, pH_u were divided into categories (Table 5.4). The majority of the results for pH_u were within the range of ≤ 5.6 (Table 5.4). It was notable that while the Dorper, NA x D cross and SAMM x D cross mostly had a pH_u averaging 5.60 or less, only 47% of the Namaqua Afrikaner meat had a pH_u of less than 5.80, 38% had a pH_u larger than 5.81 and 15% had a pH_u higher than 6.00 (Tables 5.2 & 5.4). On the other hand, the majority of SAMM lambs had a pH_u equal to or greater than 5.81 (55%) and 10% greater or equal to 6.0, while only 35% attained a pH_u of less than 5.80 (Table 5.4). Similar results with regards to another fat-tailed breed (Damara) compared to the Dorper have been reported (Almeida *et al.*, 2013). These results were obtained from seasonal weight loss trails – depicting a growth and a restricted feeding scenario. It is known that nutritional stress will result in a higher pH_u of the meat. The pH_u of the Damara (5.78 ± 0.05) were lower than the Dorper's (5.89 ± 0.06) when not under nutritional stress. In addition, when being exposed to restricted feeding and therefore being nutritionally stressed, the fat-tailed Damara's pH_u (5.83 ±0.04) were still lower than that of the Dorper (5.96 ± 0.08) – possibly illustrating the ability of the fat-tailed breed to withstand nutritional stress by offsetting it through use of surplus fat stored in the fat-tail (Almeida *et al.*, 2013). The Australian Merino was also included in the study and while its pH_u was similar to that of the Damara on a high nutritional plane, when under nutritional stress, it also reached a higher pH_u, similar to that of the Dorper (Almeida *et al.*, 2013).

A pH_u of 5.3 to 5.8 is deemed as normal, while dark-cutting or dark-firm-dry meat is observed at a $pH_u > 6.0$ (Honikel, 2004a). However, according to Silva *et al.* (1999), pH 5.8 should be regarded as moderate DFD (normal = pH 5.5 to 5.8; moderate DFD = $5.8 < pH < 6.2$ and DFD = pH 6.2 to 6.7). Therefore, it seems that the meat of the SAMM (55%) tends towards a moderate DFD, while 10% should show indications of DFD. For Namaqua Afrikaner meat a similar argument is given with 38% higher than 5.8 and 15% higher than 6.0 for pH_u. A possible reason for the Namaqua Afrikaner having a higher pH_u could be linked to the temperament of this breed; they are known to be more flighty and "wild" than the more domesticated Dorper breed (anecdotal data with preliminary results from Cloete *et al.*, 2013). It is well know that flighty animals are more stressed when exposed to pre-slaughter stress, resulting in a greater chance of glycogen depletion, with the final outcome being a high(er) pH_u (Priolo *et al.*, 2001; Honikel, 2004b; Cloete *et al.*, 2005). This scenario is exacerbated by the lower IMF content (%) of the Namaqua Afrikaner meat (Tables 5.7 & 5.9).

Furthermore, the lower SCF cover of the SAMM and less uniform SCF cover of the Namaqua Afrikaner (Table 5.2) will result in faster cooling of their carcasses. It has been reported that fatter carcasses cool down at a slower rate due to the insulating effect of the thicker SCF cover, resulting in a faster pH decline and thus a lower pH_u (Priolo *et al.*, 2001) - even though only very moderate inverse correlations between pH_u and SCF cover at 13 rib ($r = -0.374$; $P < 0.001$) and the $3^{rd}/4^{th}$ lumbar vertebrae ($r = -0.353$; $P < 0.001$) were observed.

5.4.2.2 Subcutaneous fat (SCF) depth and tail fat

The results of this study are partially consistent to those found in literature. Cloete (2007) reported breed (Dorper vs. SAMM x D) differences in SCF depth at both sites measured. However differences attributable to production year were also reported (Cloete, 2007) – which was not the case in the present study. Furthermore, although it was reported that the Dorper carcass had the thickest SCF layer, similar to the present study, a lower ($P \leq 0.05$) SCF depth for both sites measured were reported for the SAMM x D cross (Cloete, 2007). Although no significant differences were found in the present study between the Dorper and SAMM x D cross, the absolute values were in the same direction (Cloete, 2007). The relatively small number of SAMM x D lambs possibly did not allow for the detection of such a small difference as significant. Breed differences between thin-tailed Dorper and fat-tailed Namaqua Afrikaner breed as found in the current study were consistent with those reported by Yousefi *et al*. (2012).

The most plausible explanations for these differences (Table 5.2) are found in the differences in chronological age at which these lambs will reach physiological maturity, as well as the dissimilarities in the localities of fat depots in the bodies of the different breeds/crosses. Furthermore, upon appraisal for being slaughter ready the lambs were visually assessed according to SCF cover in the lumbar region of the back. Being an unimproved fat-tailed breed, the body conformation and SCF deposition in the lumbar region of the Namaqua Afrikaner will be different from the other breeds or crossbred genotypes. Fat-tailed sheep have a less uniform SCF cover – as mentioned, the majority of surplus fat in the Namaqua Afrikaner's carcass is stored in the fat-tail, but the proximity of the lumbar region to the fat-tail results in fat being deposited in the dorsal region as well, while less fat is deposited around the sides and belly of the animal. Therefore, it can be argued that upon visual appraisal for slaughter readiness according to the extent of the SCF in the dorsal region a false assessment of being "slaughter ready" could have been given in the case of the Namaqua Afrikaner lambs. This argument is substantiated by the lighter mean slaughter (live) weight of the Namaqua Afrikaner as well, which was below all those of the other pure breeds or crossbred genotypes (Table 5.2).

As a result it would seem that Namaqua Afrikaner lambs might not have been slaughter ready yet and therefore slaughtered at too young a chronological age. In addition it can be argued that, as a result of the unimproved and late maturing nature of the Namaqua Afrikaner, lambs from different breeds are not at the same/similar stages on the process of reaching physiological maturity. The Dorper is regarded as an early maturing breed, whereas the both the SAMM and Namaqua Afrikaner are late maturing (Epstein, 1960; Webb & Casey, 1995; Cloete *et al.*, 2000; Milne, 2000; Cloete *et al.*, 2007; Cloete *et al.*, 2012). This reasoning implies that the purebred Dorper would have been closer to physiological maturity and the onset of the fattening phase, than the late maturing breeds would be (Pállson, 1955; Butterfield, 1988a; Butterfield, 1988b; Lawrie & Ledward, 2006b; Cloete *et al.*, 2012). A phenomenon which is also noticeable in the differences in fatness classes ($P < 0.001$) allocated as per Government Gazette (GG 14060, 1992, R1748). In

South Africa lamb carcasses are graded according to the age of the animal and the fat depth ranging from 0 mm (none) to 6 mm (excessively overfat). In this study all lambs were slaughtered before they had 2 permanent incisors and so were graded A (GG 14060, 1992, R1748). The highest age (A) and fatness (0-6) scores allocated to the Namaqua Afrikaner and SAMM were only A2, while some of the Dorper lambs were allocated A4; indicating a thick SCF coverage. The highest fatness scores were given to the NA x D cross at A6 (excessively over-fat). The SAMM x D cross were intermediate at A3. It is known that even if slaughtered at the same chronological age late maturing breeds still have the advantage of producing a leaner carcass, attributable to the later onset of the fattening phase (Cloete *et al*., 2007; Cloete *et al*., 2012).

Differences in the localities of fat depot's, particularly in the subcutaneous and caudal regions, is deemed as another reason driving the differences in SCF depth in this study – a reason, perhaps, of greater importance (Epstein, 1960; Hugo, 1966; Brand, 2000; Milne, 2000; Ramsay *et al.,* 2001; Almeida, 2011a). Specifically, the distribution of surplus fat in the carcass of the fat-tailed Namaqua Afrikaner differs from the other thin-tailed pure breeds; attributable to differences in their genetic make-up (Buduram, 2004; Soma, 2012). As the Namaqua Afrikaner is indigenous to severely arid regions, it has developed and adapted to surviving in warmer, drier climates. One of these adaptive traits is its fat-tail, of which the biological functionality on occasion has been compared to that of the hump of a camel (Epstein, 1960; Hugo, 1966; Almeida, 2011b). The development of a subcutaneous layer of fat (SCF), used for insulation against the colder European climates as seen in the imported breeds, would impede cutaneous thermolysis and would reduce the survival rates of animals in hot and humid environments (Ermias *et al*., 2002; Lawrie & Ledward, 2006b). As a result the fat-tail not only acts as a depot for reserve fat when food is abundant, which can then be utilised during times of drought or when migrating, but also assists in alleviating thermal stress (Ermias *et al*., 2002; Lawrie & Ledward, 2006b). Consequently, when maturity is reached and the fattening phase sets in, the Namaqua Afrikaner will store the bulk of its surplus fat in its fat-tail, with only minor fat deposits (in comparison) to be found in the rest of the carcass – as opposed to the Dorper, SAMM, as well as the SAMM x D cross, being docked and storing surplus fat subcutaneously (Epstein, 1960; Mason & Maule, 1960; Epstein, 1971). Furthermore, not only do camels store their surplus energy in the hump, as an additional adaptive trait to desert regions the camel will position its body in the day towards the sun; at such an angle at which the body surface area exposed to radiation is the least (Mukasa-Mugerwa, 1981). Although limited information is available on this topic, it can be postulated that the Namaqua Afrikaner could exhibit similar behaviour and that the thicker fat cover of the dorsal region of the Namaqua Afrikaner could have a similar property, i.e. protection from radiation.

It was also noted that while production year did not have an effect on SCF depth (P = 0.423) (Table 5.1), that the rainfall in 2011 (118 mm) and 2012 (159 mm) were substantially lower than in 2010 (237 mm) or than the average annual rainfall for the research farm of 221 mm. It is expected that when the rainfall is low (nutritional stress) the SAMM will have lower SCF depth and be similar to the Namaqua Afrikaner. When rainfall is high the SAMM will have thicker SCF layer but the Namaqua Afrikaner will still have the same SCF thickness, but a heavier fat-tail. An interesting observation made was that although it is expected that the SCF depth of the Namaqua Afrikaner would be very low, for all three production years it was similar to that of the SAMM, a thin-tailed breed storing excess fat subcutaneously – it could be argued that this phenomenon is attributable to the Namaqua Afrikaner's adaptation to survival on a lower plane of nutrition.

Unfortunately tail weights were only available for 2012, during which the thin tailed breeds were not docked. As expected the fat-tail of the Namaqua Afrikaner (493.3 ± 38.28 g) weighed significantly more than the tails of the other breeds/crosses. Understandingly, while the genetic makeup of the NA x D cross entails 50% Namaqua Afrikaner, the breed with the second largest tail was the NA x D cross (258 ± 51.15 g). The tails of the other two breeds and the crossbred genotype all weighed less than 100 g.

5.4.2.3 Drip loss (%) and cooking loss (%)

Apart from the SAMM differing from the other breeds, the results for percentage cooking loss is supported by literature. In two separate studies: one on the effect of sire breed on the carcass traits of terminal crossbred lambs (Cloete, 2007) and the other on the effect of breed on the slaughter traits on different Merino-type breeds (Cloete et al., 2012), no differences in percentage cooking loss were observed ($P > 0.05$). Differences in percentage drip and cooking loss as a result of different production years were also reported by Cloete (2007). Hoffman et al. (2003) did not report any breed differences on comparison of the cooking loss (%) of samples from different terminal crossbred lambs. Similarly, Esenbuga et al. (2009) did not record any differences in percentage cooking loss between fat-tailed Awassi and Morkaraman lambs, nor were any differences observed between the fat-tailed Chall and thin-tailed Zel breeds (Yousefi et al., 2012).

Although no significant correlation was observed between the pooled results (of all the breeds) of percentage drip loss and pH_u ($r = 0.073$; $P = 0.235$) in this study, it is known that a relationship between drip loss and the ultimate pH of the meat normally exists (Warriss, 2000a). Thomas *et al.* (2004) noted that this relationship will be observed as an inverse correlation between pH_u and percentage drip loss. A high pH_u will thus result in a high water holding capacity and a resultant low drip loss percentage – even though the results of the present study are inconclusive in this regard as seen from the low positive correlation between pH_u and drip loss (%) presented earlier. Although a significant correlation between drip loss (%) and IMF content (%) (discussed in section 5.4.3) was not observed ($r = -0.067$; $P = 0.292$) in the present investigation, it has been postulated that the IMF surrounding the myofibrils act as a barrier to water loss, reducing both drip and cooking loss (Yousefi *et al.*, 2012). Additionally, Thomas *et al*. (2004) also stated that drip loss is inversely correlated with cooking loss, thus when a low drip loss (%) is recorded more water is available to be lost during cooking and a higher cooking loss (%) is expected. In this investigation, a negative correlation existed between drip loss and cooking loss ($r = -0.501$; $P < 0.001$).

5.4.2.4 Colour

The colour of meat plays an important role in influencing consumer purchase intent. It is one of the few attributes of quality that can be reviewed at point of purchase and is also often seen as an indicator of freshness (Warriss, 2000a; Grunert *et al.*, 2004). In general consumers expect the colour of meat to be a bright red i.e. the colour of oxy-myoglobin (Lawrie & Ledward, 2006a).

The SAMM and Namaqua Afrikaner were the breeds with the highest pH_u recorded and at the same time also the highest L* values, indicating a lighter meat colour. These results are in contrast with those reported in the literature – it is expected that meat with a higher pH_u will have a lower L* value and thus a darker colour (Warriss, 2000a; Geldenhuys *et al.*, 2014) however, it should be noted that the magnitude of the differences in mean L* values were very small (~3 units) (Table 5.2). It is also expected that muscles with higher IMF content (%) will have a higher L* value as fat has a higher light scattering or reflectance property than protein (Hedrick *et al.*, 1983). Again, the results proved to be counter-intuitive as the breeds with the lower IMF content (%) (Table 5.7) had the higher L* scores (Table 5.2).

No breed differences were observed in any of the other colour traits measured, but a*, hue and Chroma were influenced by production year (Tables 5.1 & 5.3). Upon comparison of the pooled results of the different parameters, the a* value is correlated with myoglobin content of the muscle (not measured in this study), and had a strong correlation with Chroma ($r = 0.943$; $P < 0.001$) and a strong inverse correlation with hue ($r = -0.700$; $P < 0.001$). A greater IMF content (discussed in section 5.4.3) (Tables 5.6 & 5.8) influences the colour of the meat by increasing oxidative instability (Sañudo *et al.*, 1998; Vergara *et al.*, 1999) resulting in animals with a greater carcass fat content, such as the SAMM x D (Table 5.7), needing an increased myoglobin content to sustain the increased demand for oxygen and thus resulting in a more vividly red colour (Renerre, 1986; as cited by Yousefi *et al.*, 2012). Unfortunately the results of the present study is inconclusive in this regard as the correlation between IMF content and the a* value was not significant ($r = 0.011$; $P = 0.867$) and breed differences in th a* value were not observed (Tables 5.1 & 5.2).

5.4.2.5 Warner-Bratzler shear force (Instrumental tenderness)

Scrutinising data with regard to climate and rainfall on Nortier Research farm over the three years, it was noticeable that in 2011 only 118 mm of rainfall was received as opposed to the expected annual average of 221 mm, while in 2012 the annual rainfall was 159 mm and in 2010 237 mm. When scarcities of forage are prevalent and extensively kept sheep have to walk longer distances to find adequate grazing, an increase in muscle activity is expected. However, the *longissimus lumborum* is a postural muscle and flexes the spine laterally; therefore its workload should not increase with an increased grazing activity (Frandson *et al*., 2003). Furthermore, studies on Texel x Romney crossbred progeny showed that between 100-215 days of age breed does not have a marked effect of the collagen content of muscle (Young & Dobbie, 1994), which suggests that terminal sire breed will not influence shear force/tenderness of the meat (Cloete, 2007). Therefore it is postulated that the most probable cause for the differences in tenderness over years is a result of the lower percentage of IMF in the LL muscles of the 2011 lambs. Although an interaction between breed and production year was recorded for IMF content (%), (discussed in section 5.4.3) it was still clear that the results for the lambs of 2011 were the lowest ($P \leq 0.05$) (Table 5.8). IMF content has a diluting effect on the perimysial collagen fibres by interrupting the structure thereof and consequently reducing the shear force (Schönfeldt, 1993; Warriss, 2000a; Warner, 2010), an observation substantiated by the moderate inverse correlation observed between shear force and IMF content (%) ($r = -0.318$; $P < 0.001$).

Yousefi *et al.* (2012) reported differences ($P < 0.001$) between the fat-tailed Chall (higher shear force) and the thin-tailed Zel (lower shear force) sheep breeds. Breed differences were also reported by other authors investigating Dorpers, SAMM and their respective crossbred progeny (Hoffman *et al*., 2003; Cloete, 2007; Cloete *et al*., 2012). However, in agreement with the study of Cloete (2007), in the present study differences in the shear force values were recorded as a result of production year ($P = 0.001$).

5.4.3 Proximate composition

The only sample having lower moisture content (%) than the three pure breeds were the SAMM x D cross. At the same time this genotype also contained the highest quantity of fat (2.8 ± 0.11; $P < 0.001$) in absolute terms. This is to be expected as an inverse relationship ($r = -0.786$; $P < 0.001$) exists between the IMF content of the meat and its moisture content. Usually, when the IMF content starts to increase, moisture content of the muscle tends to decrease (Strasburg *et al.*, 2008). Also, an inverse correlation were found between moisture content (%) of the meat and the protein content (%) ($r = -0.817$; $P < 0.001$), while protein and IMF content (%) were moderately positively correlated ($r = 0.451$; $P < 0.001$). It was also noted that in absolute terms the Namaqua Afrikaner had the highest and lowest percentage moisture and fat (%), respectively (Table 5.6). This finding was expected and results from the fact that the Namaqua Afrikaner mainly deposits fat in the tail and not in the intramuscular depots. Furthermore, the proximate composition of the NA x D was regarded as intermediate with regard to moisture and protein and compared favourably with the Dorper and SAMM in terms of IMF content ($P > 0.05$). This was expected, considering that the Namaqua Afrikaner contributed 50% to the germplasm of the latter cross.

Differences in proximate composition as a result of production year (Table 5.8) can be explained in the same manner. With inverse correlation between moisture content and fat content, it can be seen that the moisture content (%) of the 2010 samples was the lowest and the IMF content (%) for the same year the highest. Inverse results were recorded for 2011 samples;

moisture content (%) being the highest and IMF content (%) the lowest. As discussed earlier, during 2011 (118 mm) the rainfall in the region was much lower than the annual average of 221 mm, resulting in less natural grazing available. As a result the animals were under nutritional stress and less energy was stored as surplus fat in the IMF depots. In contrast, during 2010 the rainfall was higher (237 mm) than the annual average, and as a result more grazing was available. Animals thus had enough available food, and surplus could be stored in the form of fat. The intermediate nature of the 2012 samples can be explained by the fact that the rainfall of 2012 was also intermediate at 159 mm.

5.5 Conclusions

The main aim of the study was to determine how the meat quality (physical attributes and proximate composition) of the indigenous fat-tailed Namaqua Afrikaner sheep compares with that of the two commercial breeds i.e. the Dorper and the SAMM and the respective crossbred genotypes. Although clearly disadvantaged in terms of size, the profile of the physical attributes of the meat from Namaqua Afrikaner lambs was similar to that of the SAMM, comparing favourably with this dual-purpose breed. Apart from pH_{45} the NA x D compared well with the Dorper for both physical attributes and proximate composition, providing the opportunity for future research to investigate the meat quality of terminal crossbred progeny from Namaqua Afrikaner sires. The nutritional profile of Namaqua Afrikaner lambs contained the least amount of fat, a positive attribute, which if marketed correctly could enhance the commercial profile of this breed. The most important finding was that the meat of the Namaqua Afrikaner compared well in terms of shear force with the other breeds/crosses, implying that its meat should not be less tender despite the lower intramuscular fat content thereof. Thus determining the sensory profile of the Namaqua Afrikaner would elucidate the future possibility of consumers accepting the eating quality of the Namaqua Afrikaner meat.

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CHAPTER 6

Comparison of the sensory profile of the indigenous fat-tailed Namaqua Afrikaner with Dorper and Namaqua Afrikaner x Dorper lambs reared under extensive conditions[2]

Abstract

Changes in climate patterns may have an impact on the sustainability of South African agriculture and specifically lamb/mutton production. Researchers thus have begun to investigate the possibilities of farming with indigenous breeds, presumably well adapted to the harsh climates in South Africa. At the moment there is no information available on the sensory profile of the indigenous fat-tailed Namaqua Afrikaner, thus the aim of this study was to compile and compare such a profile relative to that of the Dorper, South Africa's main commercial meat breed. Lambs from the Namaqua Afrikaner x Dorper crossbred genotype (NA x D) were also included in the study. Lambs were selected on visual appraisal as being ready for slaughter. Descriptive sensory analysis was carried out to determine the primary sensory characteristics of the *longissimus lumborum*. Eleven sensory descriptors, including flavour, aroma and texture attributes, were identified by the trained sensory panel. No significant differences were reported for most of the attributes, i.e. lamb aroma; fatty aroma; overall lamb flavour; herbaceous bush-like flavour and aroma; (visible) fibres; initial and sustained juiciness; metallic taste and residue. The only sensory attribute for which a difference was reported was tenderness (first bite), with Namaqua Afrikaner scoring the lowest (least tender) and the NA x D cross the highest (most tender). No differences were seen between NA x D cross and the Dorper samples for this attribute. Tenderness was also highly correlated to other sensory attributes: overall lamb flavour, initial and sustained juiciness, as well as the intramuscular fat content (%). From the results of the study it can be concluded that the overall sensory profile of the Namaqua Afrikaner did not differ significantly from that of Dorper, except for tenderness.

Keywords: Carcass characteristics, early maturing, indigenous, instrumental parameters, late maturing, physical attributes, proximate composition, tenderness, unimproved

6.1 Introduction

Not only do humans consume food as a means of staying alive, i.e. with food being the primary source of nutrients and energy, but food is also consumed for the pleasure of eating, i.e. enjoying

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[2] Hoffman, L.C., Burger, A., Cloete, J.J.E., Muller, M. & Cloete, S.W.P. (2014). Comparison of the sensory profile of Namaqua Afrikaner, Dorper and Namaqua Afrikaner x Dorper lambs reared under extensive conditions. *Proc. of the 47th Congress of the South African Society of Animal Science,* Pretoria, South Africa. 6-8 July (Presentation).

food varying in different flavours and textures (Chen, 2009). Sensory analysis is usually performed when it is important to determine the full sensory profile of a product or a range of products. Sensory analysis can be defined as: "a scientific discipline used to evoke, measure, analyse and, interpret reactions to those characteristics of food as they are perceived by the senses of sight, smell, taste, touch and hearing" (Stone & Sidel, 2004; as cited by Lawless & Heymann, 2010).

The sensory profile of meat is multi-faceted and meat from different species can differ in terms of aroma, flavour and taste, but also in terms of textural quality attributes, i.e. juiciness and tenderness. Although certain ethnic groups prefer tougher meat (Warriss, 2000a; Lawrie & Ledward, 2006), research has indicated that consumers are willing to pay higher prices for more tender meat (Miller *et al*., 2001; Miller, 2002). Overall tenderness is regarded as one of the most important sensory qualities when considering all types of meat (Whipple *et al.,* 1990; Warriss, 2000a; Pietrasik & Shand, 2004). Tenderness is especially important with beef, but for mutton or lamb the distinctive species-specific flavours are considered to be the most important attributes; followed by tenderness and then juiciness (Watkins *et al.*, 2013). The compounds responsible for species-specific and other flavour notes are usually lipid-soluble and influenced by the quantity of fat in the carcass and the chemical composition (fatty acid profile) thereof (Lindsay, 2008). Of the main flavour notes found in sheep meat, the so-called *mutton flavour* is related to the animal's age and is thus found to be more perceptible in cooked meat from older animals. Alternatively, *pastoral flavour* is related to the diet of the sheep; hence variations in diet composition will not only affect the amount of fat deposited intramuscularly but also the chemical composition and profile of the fatty acids in said fat depot's (Vasta & Priolo, 2006; Lindsay, 2008; Watkins *et al.*, 2013).

The Dorper breed was developed during the 1930's as a result of the inferior carcass conformation of the fat-tailed breeds then farmed with not being acceptable to the British consumer (Nel 1993; Milne, 2000). Currently the Dorper is considered the largest commercially farmed meat breed within South Africa (Cloete & Olivier, 2010). It has excellent carcass characteristics as its development is the result of selective breeding for carcass quality and yield (Webb & Casey, 1995; Brand, 2000; Milne, 2000; Ramsay *et al.,* 2001; Snowder & Duckett, 2003).

However, in recent years consumers have given preference to lean red meat products as a result of previous research studies linking the consumption of red meat and animal fat to non-communicable life-style diseases associated with the western diet (Higgs, 2000; Jiménez-Colmenero *et al*., 2001; Wood *et al.*, 2003; Biesalski, 2005; McNeill & Van Elswyk, 2012). Dietary advice has thus focused on the detrimental association between the saturated fatty acids (SFA) found in red meat and a significant dietary intake of SFAs and the effect thereof on these non-communicable diseases, including certain cancers and coronary heart diseases (CHD) (Higgs, 2000; Wood *et al.*, 2003; Keleman *et al.*, 2005; Larsson *et al.*, 2005; Sinha *et al.*, 2005; Steffen *et al.*, 2005; Cross *et al.*, 2007, Azadbakht & Esmaillzadeh, 2008; McAfee *et al.*, 2010). The importance of differentiating between processed meat products and unprocessed meat has, however, been emphasised in recent research (Binnie *et al.*, 2014) as no significant correlation between CHD and the moderate consumption of unprocessed red meat has been illustrated (McAfee *et al.*, 2010; Micha *et al.*, 2010; McNeill & Van Elswyk, 2012; Kappeler *et al.*, 2013; Rohrmann *et al.*, 2013; Binnie *et al.*, 2014).

Being an early maturing breed, Dorper lambs can become too fat as a result of their faster growth rate and the development of subcutaneous fat depot's (Cloete *et al.*, 2007). The cost of depositing fat, when measured in terms of feed energy, is far greater than the energy needed to lay down muscle tissue (Kashan *et al.*, 2005). Presently, visible fat is being trimmed of carcasses, especially at butcheries but also by the end consumer, thus ensuring that the end product contains minimal fat (Higgs, 2000). Acquiring a lamb with a higher lean muscle to fat ratio can be achieved by utilising late maturing breeds, i.e. developing carcasses with more evenly distributed muscle tone and less fat, as opposed to early maturing breeds (Cloete *et al*., 2007; Cloete *et al*., 2012). In addition, fat-tailed breeds store less fat subcutaneously or intramuscularly, as the main depot for storing surplus energy is their fat-tail (Epstein, 1960; Almeida, 2011a; Yousefi *et al*., 2012), thus implying a higher lean to fat ratio. The late maturing Namaqua Afrikaner sheep is such a breed – fat-tailed and indigenous to South Africa (Epstein, 1960; Snyman *et al.*, 1993; ARC, 2013). Being indigenous to harsh and arid climates prevalent in the South African agriculture, the Namaqua Afrikaner is well adapted to survive on a lower plain of nutrition, thus utilising energy stored in the fat-tail during times of drought and food scarcity (Epstein, 1960; Hugo, 1966; Epstein, 1971; Campbell, 1995; Ramsay *et al.,* 2001; Cloete & Olivier, 2010).

On the subject of the meat quality and sensory attributes of the indigenous fat-tailed Namaqua Afrikaner, information in literature could not be found – a direct result of the previously presumed inferiority in meat yield (Chapters 3 and 4) and quality of indigenous breeds (FAO, 2003), as well as their traditionally lower financial importance, especially to consumers in developed countries (Tshabalala *et al.*, 2003). Nevertheless, bearing in mind the hardiness and the lean meat yield of the Namaqua Afrikaner (Epstein, 1960; Hugo, 1966; Epstein, 1971; Snyman *et al.*, 1993, Campbell, 1995; Ramsay *et al.,* 2001; Cloete & Olivier, 2010), it is important to consider the difficulties of keeping production costs to a minimum with the majority (80%) of South African agricultural land being located in arid or semi-arid regions (Cloete & Olivier, 2010). From a health perspective it is also important to increase the production of lean meat. It thus stands to reason that the possibility of farming with indigenous fat-tailed breeds, utilising modern technologies, should be investigated (FAO, 2003; Van Marle-Köster *et al.*, 2013).

While not only influencing the flavour profile of the meat, intramuscular fat is considered to have an indirect influence on tenderness, attributable to a diluting effect of the fat on the muscle structure (Schönfeldt, 1993; Warriss, 2000a; Warner, 2010; Yousefi *et al.*, 2012). Therefore a trade-off effect between the fat content and the palatability of the meat exists (Warriss, 2000a; Webb & O'Neill, 2008). When selecting for leanness, selection against intramuscular fat content and tenderness occurs (Warriss, 2000a; Jacob & Pethick, 2014). Both the subcutaneous and intramuscular fat located in a sheep carcass has a significant impact on the final quality of the meat, influencing not only the sensory attributes (aroma, flavour, juiciness, tenderness), but also the physical characteristics (pH, thaw loss, cooking loss, colour) and nutritional value (fatty acid profile) (Wood *et al*., 2008). Therefore, highlighting the necessity of investigating said attributes of the unimproved Namaqua Afrikaner breed and comparing it to that of the commercial breeds.

The desired combination of these traits (sensory profile of the Dorper and hardiness/leanness of the Namaqua Afrikaner) may only be present in crossbred genotypes (Piedrafita *et al.*, 2010; Pannier *et al*., 2014). Crossbreeding through the mating of divergent breeds is used to improve possible commercial gain (Kinghorn & Atkins, 1987). Crossbred genotypes are known to express hybrid vigour and are commonly found to be more robust, with an improved growth (3-10%) and survival to weaning (10% direct heterosis), as well as an improved reproduction (10-40% maternal heterosis) (Fogarty, 2006). Studies on Australian lamb have shown that intramuscular fat content is also highly heritable at 0.48 (Jacob & Pethick, 2014; Mortimer *et al.*, 2014). Also, research has shown that crossbreeding Dorper dams with SAMM sires results in a lower shear force value and reduced fat depth of the *longissimus thoracis et lumborum* of the crossbred genotype (Cloete *et al.,* 2007).

In view of the above, the objective of this study was to characterise the full sensory profile of the Namaqua Afrikaner and compare it to that of the Dorper, South Africa’s main commercial meat breed. Furthermore a Namaqua Afrikaner x Dorper cross was included in the study, to determine if it is possible to obtain a cross with a sensory profile similar to that of the Dorper, but with the hardiness of the Namaqua Afrikaner.

6.2 Materials and methods

6.2.1 Experimental site and lamb management

The study was conducted on lambs raised under extensive conditions on the Nortier Research farm (32°02’06.65”S; 18°19’55.52”E), situated to the north of Lamberts Bay on the western coast of South Africa. The site and prevalent weather conditions were discussed in detail in Chapter 4 (subheading 4.2.1).

All of the lambs included in this study were born during the months of June and July 2012, with average birth weights being recorded for Dorper, Namaqua Afrikaner and the NA x D crossbred genotype, respectively (Table 6.1). Nursed and raised by their biological mothers, the lambs had the vital *ad libitum* access to colostrum within the first 24 h after birth. Together with their mothers, the lambs roamed under extensive conditions in a free range system, having *ad libitum* access to feed and water. Additional lamb management practices are documented in Chapter 4 (subheading 4.2.2). Lambs were weaned on 28 September, with average weaning ages recorded as: 100.5 ± 2.02 days, 89.9 ± 2.60 days and 94.5 ± 1.36 days for Dorper, Namaqua Afrikaner and NA x D cross lambs, respectively

6.2.2 Slaughter procedures

Thirty-six castrated male lambs of the Namaqua Afrikaner (n = 14), Dorper (n = 14) and NA x D (n = 8) crossbred genotype were randomly selected from the flock on the Nortier Research farm. Average slaughter ages were recorded as: 161.5 ± 4.04 days, 146.4 ± 3.11 days and 145.8 ± 4.54 days for Dorper, Namaqua Afrikaner and NA x D cross lambs, respectively. The lambs were weighed and selected on visual appraisal as slaughter ready. Being recorded 24 h prior to slaughter, these weights were used as slaughter weight. The lambs were loaded onto a truck and transported to Roelcor abattoir (33°27'0S; 18°41'60E), a commercial abattoir in Malmesbury; a total distance of ≈250 km on a day with a maximum temperature of 21.4°C. Slaughtering procedures took place according to standard South African procedures, as described in Chapters 4 and 5.

6.2.3 Experimental units and sample preparation

Sample preparation took place as discussed in Chapter 5 (subsection 5.2.3).

6.2.4 Descriptive sensory analysis (DSA)

6.2.4.1 Sample preparation

Descriptive sensory analysis was conducted on three treatments (two pure breeds and one cross bred genotype) over three consecutive days (two sessions per day; six samples per session). The frozen, vacuum-packed samples were removed from storage (-20°C) 24 h prior to the scheduled sensory analysis sessions, and thawed at refrigeration temperatures (4°C) as suggested by the American Meat Science Association (AMSA, 1995). Excess moisture was removed from the thawed meat samples by lightly blotting the samples with absorbent towel paper, where after the samples were weighed.

The entire LL sample was placed inside a coded, 250 x 400 mm GLAD® oven bag, which was placed on a stainless steel grill, fixed on top of an oven tray (three LL meat samples per oven tray). An electronic thermocouple probe, connected to a handheld electronic digital read-out temperature monitor (Hanna Instruments, South Africa), was inserted into each sample, parallel with the muscle fibre direction; positioning the tip of the probe at the geometric centre of the muscle sample (AMSA, 1995). The probes were used to individually monitor the core temperature of each sample while in the oven (AMSA, 1995). The oven bags were closed and tied around the probe with a plastic tie provided by the supplier.

Two conventional Defy (Model 831) ovens were preheated to 160°C (AMSA, 1995). The ovens were connected to a computerised temperature control system, responsible for regulating the temperature of the ovens (Viljoen *et al*., 2001). An oven tray containing three of the prepared samples was placed inside each of the two ovens. Individual samples were removed from the oven when reaching an internal (core) temperature of 68°C (AMSA, 1995). The samples were removed from the oven-roasting bags and allowed to cool for 10 min. Samples were not turned at any time during the cooking process, nor were any seasoning, including table salt (NaCl), added as these could have influenced the inherent flavour profile of the meat. After cooling, the samples were again gently blotted dry with absorbent paper and weighed to calculate cooking loss.

Being exposed to direct heat in the oven the outside of the sample was trimmed off to remove possible heat damaged meat, as well as remaining connective tissue or any residual subcutaneous fat as prescribed by the American Meat Science Association (AMSA, 1995). The required slices of approximately 1.5 cm thick were removed from the centre of the sample for proximate and shear force analyses. The remaining sample was cut, perpendicular to the muscle fibres, into 16 (1 cm x 1 cm) cubes. The possibility of tissue damage and thus the subsequent moisture loss were prevented by cutting the samples with a singular stroke. Each cube was wrapped in an aluminium foil square and placed in a coded glass ramekin – two individually wrapped cubes per ramekin. The coded ramekins, containing the aluminium foil wrapped cubed samples, were placed in an oven tray inside a preheated forced convection industrial oven (HOBART, France) and reheated for 10 min at 100 °C (Hoffman *et al.,* 2003; Hoffman *et al.,* 2006; Geldenhuys *et al.*, 2014). Upon removal from the Hobart oven, the samples were immediately served to the panellists for sensory analysis.

6.2.4.2 Trained panel

The sensory panel consisted of eight trained judges or panellists, selected for their experience of analysing different types of meat. To refresh and refine the judges' skill pertaining to lamb meat flavour and texture sensitivity, they were trained according to the guidelines for the sensory analysis of meat as set by the American Meat Science Association (AMSA) (1995). Descriptive sensory analysis (DSA) training was further conducted according to the consensus method as described by Lawless and Heymann (2010). The panel participated in four training sessions, during which each panellist received two cubes (1 cm^3) of meat from four reference standards, as well as two cubes (1 cm^3) from each of the three treatments. The reference standards used in the training sessions were beef fillet (very/most tender); A2 lamb loin (intermediate – tender); C2 mutton loin (least tender) and chicken (dry and mealy). The panellists identified and came to a consensus on using 11 sensory attributes for this experiment: lamb aroma; fatty aroma; "bush-like" aroma; meat fibres (visual observation); initial impression of juiciness (press-method); tenderness (first bite); sustained juiciness; residue; overall lamb flavour; "bush-like" flavour and metallic taste. Descriptions thereof were thereafter established, i.e. in accordance with the consensus method (Table 6.2) (Lawless & Heymann, 2010).

The test re-test method was used for the test phase of DSA of the lamb meat samples. As the three treatments differed in sample size, the experimental design was completely random. Six samples were presented in six sessions in a completely randomised order; as generated by Compusense *five*® (Compusense, Guelph, Canada) and analysed according to the questionnaire compiled during the training sessions. Analysis of the samples were done on 100 mm unstructured line scales; with each line scale being anchored by zero (low intensity) on the left and 100 (high intensity) on the right (AMSA, 1995). The panel members received two meat cubes for every treatment. The first was used to analyse the visual attributes and aroma, which were analysed upon removal of the aluminium foil. The second cube was used for the analysis of the flavour attributes and the resultant textural attributes. To clean and refresh their palates between tasting the different samples, the panellists were provided with distilled water and unsalted water biscuits (Carr, UK). During the sensory analysis the panellists were seated at individual sensory booths, with access to the software programme Compusense® *five*. The sensory analyses took place inside a room with artificial light and a controlled ambient temperature of 21°C (AMSA, 1995).

Table 6.1 Least square means (±SE) of the average weights and ages of the Namaqua Afrikaner, Dorper and NA x D cross lambs used in this study.

	Breeds		
Traits	**Dorper (n = 14)**	**Namaqua Afrikaner (n = 14)**	**NA x D[1] (n = 8)**
Birth weight (kg)	3.8^{b} ± 0.24	4.1^{ab} ± 0.19	4.4^{a} ± 0.23
Weaning weight (kg)	30.5^{a} ± 1.57	21.9^{b} ± 0.52	27.0^{a} ± 2.21

SE = Standard Error;
[1] NA x D = Namaqua Afrikaner x Dorper cross;
[ab] Means in the same row with different superscripts are significantly different (P ≤ 0.05).

Table 6.2 Definition and scale anchor points of the sensory attributes used during descriptive sensory analysis of NA, Dorper and NA x D cross samples.

	Sensory attributes[#]	**Abbreviation**	**Descriptions**	**Scale values**
1st cube	Lamb aroma	LambAr	Aroma associated with lamb meat upon removal of aluminium foil	0 = Extremely bland 100 = Extremely intense
	Fatty aroma	FattyAr	Aroma associated with lamb fat upon removal of aluminium foil	0 = Extremely bland 100 = Extremely intense
	Bush-like aroma	Bush-likeAr	Herbaceous aroma associated with "bossie" upon removal of aluminium foil	0 = None 100 = Extremely intense
	Fibres (Visual observation)	Fibres	Obvious visible differences in appearance of fibres on cut surface	0 = Coarse 100 = Fine
	Initial juiciness (Press-method)	InitialJuicy	The amount of fluid exuded on the cut surface when pressed between thumb and forefinger	0 = Extremely dry 100 = Extremely juicy
2nd cube	Tenderness (First bite)	Tenderness	The impression of tenderness after the first 2-3 chews between the molar teeth	0 = Extremely tough 100 = Extremely tender
	Sustained juiciness	SustainedJuicy	The impression of juiciness after the first 2-3 chews between the molar teeth	0 = Extremely dry 100 = Extremely juicy
	Residue	Residue	The amount of residue left in the mouth after the first 20-30 chews (before swallowing)	0 = None 100 = Abundant
	Overall lamb flavour	LambFl	Combination of taste and swallowing associated with lamb	0 = Extremely bland 100 = Extremely intense
	Bush-like flavour	Bush-likeFl	Flavour associated with "bossie"	0 = None 100 = Extremely intense
	Metallic taste	Metallic taste	Metallic aftertaste perceived prior to swallowing	0 = None 100 = Intense

[#] Aroma and flavour were analysed orthonasally and retronasally, respectively.

6.2.5 Physical measurements

6.2.5.1 pH and temperature

The pH and temperature of the left *longissimus thoracis et lumborum* (LTL) was measured as described in Chapter 5 (subsection 5.2.4.1).

6.2.5.2 Thaw loss

Percentage thaw loss (%) was calculated according to the method described by AMSA (1995). Weight before freezing (initial weight, W_1) and after thawing (final weight, W_2) were recorded and used in the calculation of thaw loss, expressing it as a percentage of the initial weight of the sample:

$$\text{Thaw loss (\%)} = ((W_1 - W_2) / W_1) \times 100\%$$

6.2.5.3 Cooking loss

Percentage cooking loss (%) was calculated according to the method as described by AMSA (1995). Weights before cooking (initial weight, W1) and after cooking (final weight, W2) were used in the calculation of cooking loss, expressing it as a percentage of the initial weight of the sample:

$$\text{Cooking loss (\%)} = ((W_1 - W_2) / W_1) \times 100\%$$

6.2.5.4 Instrumental tenderness / shear force

The instrumental tenderness or shear force of the cooked meat samples was measured using the Warner Bratzler shear force test (WBSF), as described by Honikel (1998). After cooking and trimming of the meat samples a sub-sample of ≈1.5-2.5 cm thick were removed from the LL muscle and prepared for tenderness analysis using the Warner-Bratzler sheer force method (Honikel, 1998). Analyses of the samples for WBSF are described in Chapter 5 (subsection 5.2.4.6).

6.2.5.5 Surface colour

Evaluation of the surface colour of the meat were commenced by exposing the freshly cut sub-samples (to be used for cooking loss – Chapter 5) to the atmosphere for 30 min, allowing time to bloom (oxygenate) (Honikel, 1998). Using a calibrated handheld Color-guide 45°/0° colorimeter (BYK-Gardner GmbH, Gerestried, Germany) three measurements were taken at random locations on the bloomed surface to determine the CIEL* (lightness), a* (green-red range) and b* (blue-yellow range) values. The Chroma (C*) (colour intensity/saturation) and hue angle (h_{ab}) (°) (colour definition/dimension) were calculated by using the a* and b* values (Honikel, 1998):

$$\text{Chroma } (C^*) = ((a^*)^2 + (b^*)^2)^{-0.5}$$

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

The colorimeter was calibrated using the green, black ($L^* = 0$) and white ($L^* = 100$) standards as provided.

6.2.6 Proximate composition

After cooking and trimming of the meat samples a sub-sample of ≈1.5-2.5 cm thick was removed from the muscle. This sub-sample was finely cut into smaller pieces, which were placed in a pre-weighed plastic container, weighed to the nearest gram and stored at -20°C until frozen solid.

Freeze-drying procedures and Near Infrared (NIR) spectroscopy analysis of the samples are explained in detail in Chapter 5. Wet chemistry was also done on these samples according to AOAC methods (AOAC, 2002), also explained in detail in Chapter 5.

6.2.7 Statistical analyses

A completely randomised design, with genotype (Dorper, Namaqua Afrikaner and NA x D) as the main effect, was used for analyses of the sensory data.

The following model was used: $y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$, where:

- $y_{ij:}$ the response on treatment i in replication j
- μ: the overall mean
- $\alpha_{i:}$ the effect due to genotype i
- $\varepsilon_{ij:}$ the random error associated with response on breed i in replication j.

Analysis of variance (ANOVA) was done on all variables accessed (sensory attributes, physical attributes and chemical composition) by making use of the general linear models (GLM) procedure of SAS^{TM} software (Version 9.2, 2006, SAS Institute Inc., Cary, NC, USA). Testing for panel-reliability was done by pre-processing of the sensory data and subjecting it a test-retest analysis of variance (ANOVA) using SAS. Judge*Replication and Judge*Sample interactions were used respectively as measures of temporal stability (precision) and internal consistency (homogeneity) of the panel. The Shapiro-Wilk test was performed on the standardized residuals from the model to test for normality (Shapiro & Wilk, 1965). In cases where there was significant deviation from normality, outliers were removed when the standardised residual for an observation deviated with more than three standard deviations from the model value. A probability level of 5% was considered significant for all significance tests. Least square means (LSM) (± SE) were calculated and used to correct for the unbalanced data. R-square Type III P-values were used to test for significant differences.

In addition to the ANOVAs, the data was also subjected to multivariate methods such as principal component analysis (PCA) and discriminant analysis (DA) (XLStat®, Version 2014, Addinsoft, New York, USA) to visualise and elucidate the relationships between the samples and their attributes (Næs *et al.*, 2010). Pearson correlation analysis was also used to determine correlations between different sensory, physical and proximate attributes (Snedecor & Cochran, 1980).

6.3 Results

6.3.1 Sensory attributes

The results of the analysis of variance (ANOVA) indicated that the trained sensory panel did not observe any differences between the three breeds for the following attributes: both lamb aroma and overall lamb flavour; fatty aroma; (visible) fibres; initial juiciness; sustained juiciness; both bush-like aroma and flavour; metallic taste and residue ($P > 0.05$) (Table 6.3). Still, although not significantly different overall, a tendency towards differences was observed for overall lamb flavour, as well as bush-like aroma (Table 6.3). For both these two attributes (overall lamb flavour and bush-like aroma) the t-test results indicated a significant difference between breeds (Table 6.3). In the case of overall lamb flavour the scores were 76.8 ± 0.84; 74.1 ± 0.84; and 75.4 ± 1.11 for Dorper, Namaqua Afrikaner and NA x D cross respectively, with the Dorper and Namaqua Afrikaner differing significantly from each other, while the NA x D was intermediate and did not differ from either of the other breeds. Although these values are statistically different, when judging the results on a 100-point line scale, these values seem close together and therefore it can be argued that these values can be regarded as being similar from a biological point of view. The same argument can also be given for bush-like aroma. Furthermore, bush-like aroma was scored at an intensity of <5 on a 100-point intensity scale, i.e. an intensity that is barely perceptible when conducting sensory analysis.

The only sensory attribute where the panel did observe a difference between the two pure breeds and the crossbred genotype was tenderness (first bite) ($P = 0.015$), with the Namaqua Afrikaner meat being judged as the least tender (71.1 ± 1.60); significantly less tender than both the NA x D cross (82.7 ± 2.26) and Dorper samples (78.6 ± 1.60; $P = 0.004$) (Table 6.3). No difference was observed for tenderness between the Dorper and the NA x D cross.

6.3.2 Physical attributes

Physical attributes for the treatments (breeds) included carcass weight, pH, temperature, depth of the subcutaneous fat (SCF) layer of the *longissimus lumborum*, thaw loss (%), cooking loss (%), colour and WBSF. Again the results indicated little difference between the two pure breeds and the crossbred genotype as no significant differences were observed for pH_{45}; thaw loss; cooking loss and shear force ($P > 0.05$) (Table 6.4).

A significant difference was, however, observed for slaughter (live) weight of the animals – the Namaqua Afrikaner lambs (33.6 ± 1.59 kg) weighed less than the Dorper (38.0 ± 1.44 kg) lambs, but the live weight of the NA x D lambs (35.0 ± 1.90 kg) were intermediate with the latter breed not differing significantly from the other two treatments (Table 6.4). Differences were also observed between the average carcass weight of the animals, with the Namaqua Afrikaner weighing a diminutive 12.3 ± 0.57 kg against the 15.6 ± 0.75 of the NA x D cross and the 16.7 ± 0.61 kg of the Dorper ($P < 0.001$) (Table 6.4). No significant differences were found between the

Dorper and the NA x D (Table 6.4). Similar results were reported for dressing % of the lambs – while no differences were recorded between the Dorper (47.8 ± 2.19%) and the NA x D cross (43.9 ± 4.29%), the percentage carcass yield of the Namaqua Afrikaner (37.1 ± 1.41) was substantially lower ($P = 0.008$) (Table 6.4).

Differences in pH_u were also observed, with the Namaqua Afrikaner (5.83 ± 0.04) attaining the highest pH_u and the NA x D (5.63 ± 0.05) the lowest ($P = 0.023$) (Table 6.4). The pH_u of the Dorper (5.76 ± 0.04) was intermediate and similar to that of the other genotypes.

Differences in the measurements of the subcutaneous fat depth were also recorded. At the 13th rib the Namaqua Afrikaner's SCF depth measured 1.0 ± 0.46 mm, while the Dorper and the NA x D genotypes recorded thicker SCF layers of 2.3 ± 0.46 mm and 2.7 ± 0.61 mm respectively ($P = 0.046$) (Table 6.4). Again the Dorper and NA x D did not differ significantly. Unexpectedly no differences were found between the pure breeds and cross for fat depth measured at the 3rd and 4th lumbar vertebrae ($P = 0.105$) (Table 6.4).

CIELab colour measurements indicated differences in the L* value (lightness of the meat) and the hue angle (h_{ab}) (°) (colour definition/dimension). The meat samples of the Namaqua Afrikaner (40.6 ± 0.56) were lighter than that of the Dorper (36.7 ± 0.56) and the NA x D cross (38.4 ± 0.74) ($P < 0.001$). No difference was observed between the lightness of Dorper and NA x D cross samples ($P > 0.05$) (Table 6.4). The a* value or redness of the Dorper (14.4 ± 0.43) and NA x D cross (14.7 ± 0.61) were the same, but the colour of the meat of the Namaqua Afrikaner (12.9 ± 0.43) was reported to be less vividly red. When the hue angle (h_{ab}) (°) was calculated the value of the Namaqua Afrikaner's (36.9 ± 0.82) meat samples was higher than that of the Dorper (33.0 ± 0.82) and the NA x D cross (33.9 ± 1.09; $P = 0.005$). No differences were observed for the b* value or the Chroma (C*) value ($P > 0.05$).

6.3.3 Proximate composition

Proximate analyses were performed to determine the nutritional value of the cooked meat. No differences were found for protein content (%) ($P = 0.175$) (Table 6.5). The moisture content of the Namaqua Afrikaner (67.7 ± 0.51%) compared favourably to that of the NA x D cross (66.7 ± 0.67), but was significantly more than that of the Dorper (65.7 ± 0.52%) (Table 6.5). A higher percentage of intramuscular fat was found in both NA x D (3.8 ± 0.24%) and Dorper samples (3.5 ± 0.19%) compared to the Namaqua Afrikaner (2.8 ± 0.24%; $P = 0.003$) (Table 6.5). The ash content (%) of both Namaqua Afrikaner (1.2 ± 0.01) and Dorper (1.2 ± 0.02) were higher than that of the NA x D (1.1 ± 0.04; $P = 0.044$) samples (Table 6.5).

Table 6.3 Least square means (± SE) for the sensory attributes of the meat derived from Namaqua Afrikaner, Dorper and NA x D cross.

Sensory attributes	**Breeds**			**p-value**
	Dorper (n = 14)	**Namaqua Afrikaner (n = 14)**	**NA X D[1] (n = 8)**	
Lamb aroma	76.4 ± 0.80	75.9 ± 0.80	77.4 ± 1.04	0.524
Fatty aroma	2.2 ± 0.31	2.2 ± 0.31	2.3 ± 0.41	0.963
Bush-like aroma	3.1^{a} ± 0.45	1.7^{b}± 0.45	2.5^{ab}± 0.59	0.094
Fibres (Visual observation)	72.1 ± 0.97	73.0 ± 0.97	71.06 ± 1.23	0.492
Initial juiciness (Press-method)	74.1 ± 1.46	71.1 ± 1.46	74.0 ± 1.93	0.300
Tenderness (First bite)	78.6^{a} ± 1.60	71.1^{b} ± 1.60	82.7^{a} ± 2.26	0.004
Sustained juiciness	71.2 ± 1.34	68.4 ± 1.35	72.4 ± 1.78	0.161
Residue	2.3 ± 0.49	2.7 ± 0.49	1.9 ± 0.65	0.564
Overall lamb flavour	76.8^{a} ± 0.84	74.1^{b} ± 0.84	75.4^{ab} ± 1.11	0.098
Bush-like flavour	1.5 ± 0.42	1.9 ± 0.42	1.3 ± 0.55	0.616
Metallic taste	1.2 ± 0.27	0.74 ± 0.27	1.5 ± 0.35	0.196

SE = Standard Error;
[1] NA x D = Namaqua Afrikaner x Dorper cross;
^{ab} Means in the same row with different superscripts are significantly different ($P \leq 0.05$);
Means determined by a 100-point line scale (0 = low intensity; 100 = high intensity).

Table 6.4 Least square means scores (± SE) for the physical attributes of the meat derived from Namaqua Afrikaner, Dorper and NA x D cross.

Physical attributes	**Breeds**			**p-value**
	Dorper (n = 14)	**Namaqua Afrikaner (n = 14)**	**NA X D[1] (n = 8)**	
Slaughter weight (kg)	38.0^{a} ± 1.44	33.6^{b} ± 1.59	35.0^{ab} ± 1.90	<.001
Carcass weight (kg)	16.7^{a} ± 0.61	12.3^{b} ± 0.57	15.6^{a} ± 0.75	<.001
Dressing percentage (%)	47.8^{a} ± 2.19	37.1^{b} ± 1.41	43.9^{a} ± 4.29	0.008
pH_{45}	6.89 ± 0.09	7.03 ± 0.09	7.06 ± 0.12	0.454
pH_{u}	5.76 ± 0.04	5.83 ± 0.04	5.63 ± 0.05	0.023
SCF: 13th rib (mm)	2.1^{ab} ± 0.46	1.0^{b} ± 0.46	2.7^{a} ± 0.59	0.046
SCF: 3rd/4th lumbar vertebrae (mm)	5.0 ± 0.72	3.4 ± 0.72	5.8 ± 0.95	0.105
% Thaw loss	7.8 ± 0.53	6.7 ± 0.53	7.1 ± 0.70	0.361
% Cooking loss	25.2 ± 1.61	22.6 ± 1.61	24.0 ± 2.13	0.545
WBSF (N)	30.9 ± 2.24	37.8 ± 2.24	35.2 ± 2.96	0.108
L*	36.7^{ab} ± 0.56	40.6^{a} ± 0.56	38.4^{b} ± 0.74	<.001
a*	14.4^{a} ± 0.43	12.9^{b} ± 0.43	14.7^{a} ± 0.61	0.026
b*	9.4 ± 0.39	9.7 ± 0.39	9.3 ± 0.51	0.778
Hue	33.0^{b} ± 0.55	35.7^{a} ± 0.60	34.8^{ab} ± 0.78	0.008
Chroma	17.1 ± 0.51	16.1 ± 0.51	17.6 ± 0.72	0.190

SE = Standard Error;
SCF = Subcutaneous fat;
WBSF = Warner-Bratzler shear force;
[1] NA x D = Namaqua Afrikaner x Dorper cross;
[ab] Means in the same row with different superscripts are significantly different (P ≤ 0.05).

Table 6.5 Least square means scores (± SE) for the proximate composition of the meat derived from Namaqua Afrikaner, Dorper and NA x D cross.

Proximate composition	Breeds			p-value
	Namaqua Afrikaner (n = 14)	Dorper (n = 14)	NA X D[1] (n = 8)	
Moisture (%)	67.7^{a} ± 0.51	65.7^{b} ± 0.52	66.7^{ab} ± 0.67	0.046
Protein (%)	28.3 ± 0.47	29.6 ± 0.49	28.7 ± 0.62	0.175
Fat (%)	2.8^{b} ± 0.18	3.5^{a} ± 0.19	3.8^{a} ± 0.24	0.003
Ash (%)	1.2^{a} ± 0.01	1.2^{a} ± 0.02	1.1^{b} ± 0.04	0.044

SE = Standard Error;
[1] NA x D = Namaqua Afrikaner x Dorper cross;
[ab] Means in the same row with different superscripts are significantly different (P ≤ 0.05).

6.3.4 Relationship and associations between sensory, physical and proximate characteristics

Differences or similarities in the sensory profiles of the three different meat treatments (breeds) can be visualised by making use of discriminant analysis (DA) and principal component analysis (PCA) plots. DA plots can be used to ascertain whether treatments can be grouped according to similarities of attributes.

According to the DA plot (Fig. 6.1a) there is some classification of breeds based on the sensory attributes (Fig 6.1b). The two breeds, Dorper and the NA x D cross, are situated on the left side of the DA plot and Namaqua Afrikaner on the opposite side (Fig. 6.1a). This clear categorisation on the first principal component (F1) seems to be mainly driven by the significant differences in tenderness (first bite) as also indicated in Table 6.3.

The PCA bi-plot (Fig 6.2), based on a correlation matrix, illustrates the association of all the sensory and instrumental attributes measured in this experiment, as well as the association of attributes and treatments. According to Fig. 6.2, the first two principal components, F1 and F2, explain only 41.13% of the total variance. Pearson correlation coefficients (r) were also calculated to establish whether or not the attribute associations are significant (Table 6.6). According to the PCA bi-plot (Fig. 6.2), most of the Namaqua Afrikaner samples grouped together on the left side of the PCA bi-plot associating with sensory attributes such as bush-like flavour as well as residue. Understandably this breed also associated with high levels of WBSF. Although significant differences were not reported for percentage thaw loss and cooking loss (Table 6.4), it seems that the Namaqua Afrikaner breed also showed an association with percentage thaw and cooking loss. On the right side (F2) of the PCA bi-plot the NA x D samples and the majority of the Dorper samples are grouped together, indicating associations with attributes such as intramuscular fat content (% Fat on the graph), tenderness, sustained and initial juiciness and overall lamb flavour.

It is notable that two NA x D samples were situated on the left side of F1, whereas a few of the Dorper lambs lie to the middle of F1 (Fig 6.2). This tendency could be attributed to sample differences within breeds, as it can be argued that no two meat samples will be exactly the same as a result of differences within the animals.

The associations and correlations will be discussed in detail in the following section of this chapter.

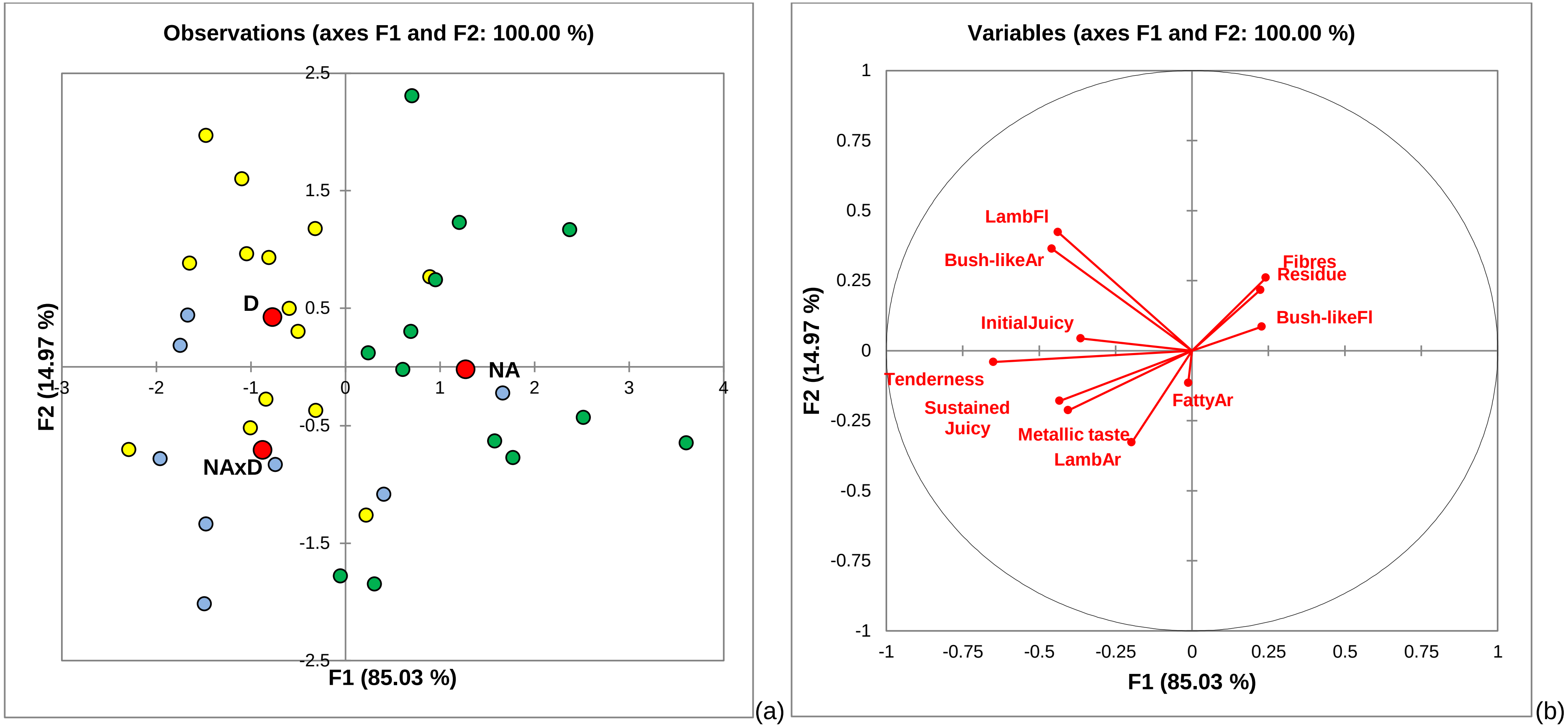

Figure 6.1 Discriminant analysis (DA) plot (a) and DA variable loadings plot (b) of the sensory attributes of lamb meat as affected by breed. (NA) Namaqua Afrikaner, (D) Dorper, (NAxD) Namaqua Afrikaner x Dorper cross. Letters following the attribute descriptors: (Fl) Flavour, (Ar) Aroma.

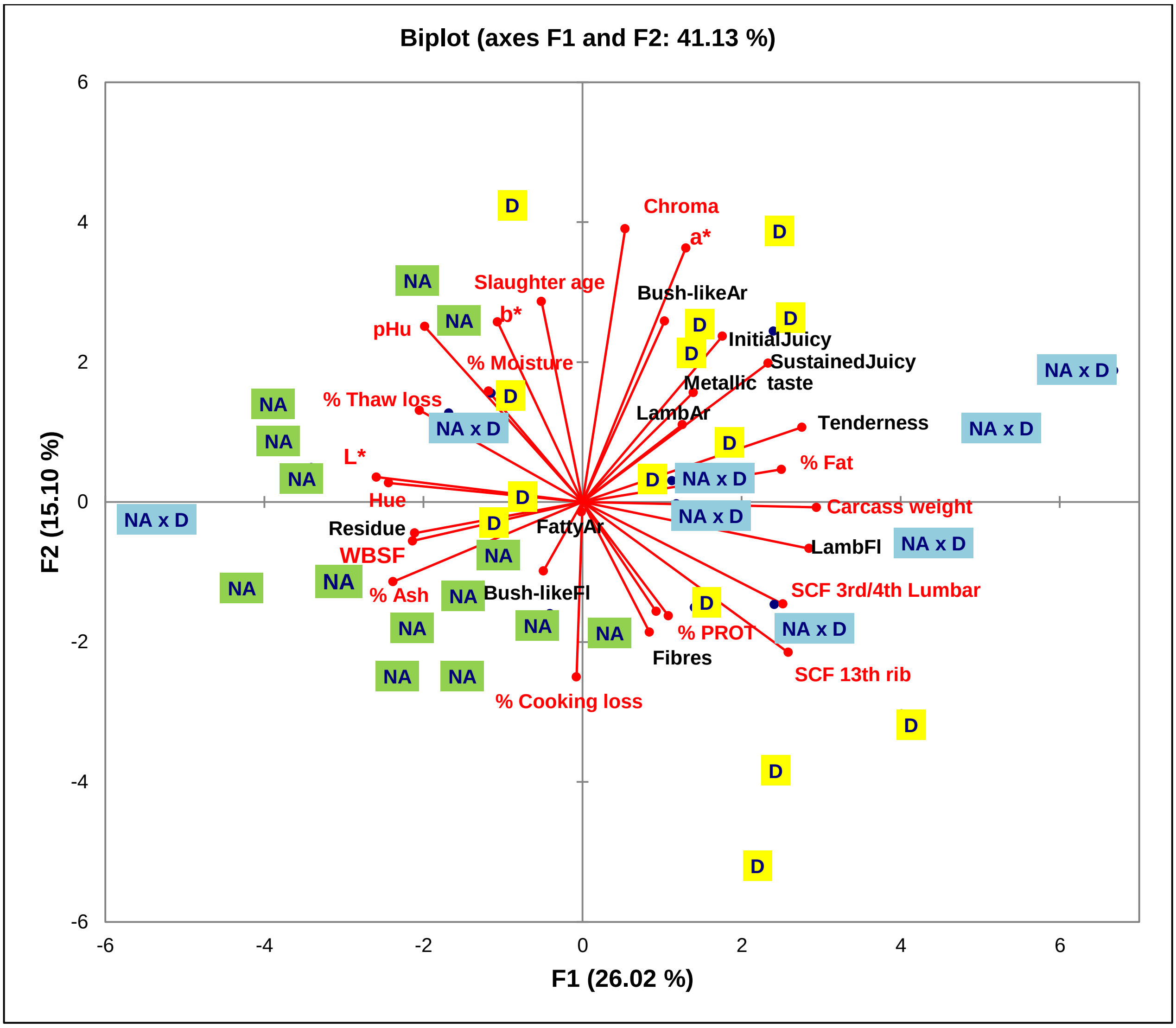

Figure 6.2 Principal component analysis (PCA) bi-plot of the sensory and physical attributes, as well as proximate composition of lamb meat as affected by breed. (NA) Namaqua Afrikaner, (D) Dorper, (NAxD) Namaqua Afrikaner x Dorper cross. Letters following the attribute descriptors: (Fl) Flavour, (Ar) Aroma. NA was represented by 14 samples, D also by 14 samples, whereas the cross breed NA x D was represented by only 8 samples.

Table 6.6 Pearson correlation coefficients (r) for the different sensory attributes and instrumental attributes measured in the Namaqua Afrikaner, Dorper and NA x D lambs. Letters following the attribute descriptors: (Fl) Flavour, (Ar) Aroma.

Variables	**Lamb Ar**	**Fatty Ar**	**Bush-like Ar**	**Fibres**	**Initial Juicy**	**Tender-ness**	**Sustained Juicy**	**Lamb Fl**	**Bush-like Fl**	**Metallic taste**	**Residue**
LambAr	**1**										**-0.344**
FattyAr	**0.384**	**1**									-0.213
Bush-likeAr	0.212	0.041	**1**								-0.214
Fibres	0.031	-0.250	-0.223	**1**							0.048
InitialJuicy	0.269	-0.071	0.208	0.024	**1**						-0.150
Tenderness	0.252	0.042	0.291	0.154	**0.483**	**1**					**-0.710**
SustainedJuicy	0.097	-0.248	0.167	0.126	**0.659**	**0.807**	**1**				**-0.482**
LambFl	0.246	-0.101	0.148	**0.392**	**0.367**	**0.686**	**0.496**	**1**			**-0.442**
Bush-likeFl	-0.088	0.226	-0.190	-0.210	-0.142	-0.209	-0.264	-0.084	**1**		0.175
Metallic taste	0.199	0.040	**0.346**	0.027	0.232	0.228	0.302	0.103	-0.114	**1**	-0.151
Residue	-0.344	-0.213	**-0.214**	0.048	-0.150	-0.710	-0.482	-0.442	0.175	**-0.151**	**1**
pH$_u$	-0.052	-0.317	0.230	0.135	0.151	0.013	0.219	-0.052	-0.247	0.157	0.092
% Thaw loss	-0.007	-0.024	0.012	0.077	-0.017	0.162	0.088	-0.006	0.069	-0.228	0.050
% Cooking loss	0.065	-0.038	**-0.329**	0.299	**-0.347**	-0.194	**-0.408**	0.003	0.021	-0.235	0.300
WBSF	-0.092	-0.081	-0.238	0.073	**-0.330**	**-0.610**	**-0.532**	**-0.535**	0.122	-0.240	**0.587**
SCF - 13th rib	**0.362**	0.246	-0.054	**0.393**	0.124	**0.426**	0.187	**0.559**	0.031	0.212	-0.215
SCF - 3rd/4th lumbar	0.209	0.021	0.089	0.269	0.074	**0.404**	0.172	**0.587**	-0.045	0.225	-0.186
L*	-0.140	-0.045	**-0.371**	-0.113	-0.291	**-0.573**	**-0.333**	**-0.421**	0.119	-0.305	**0.421**
a*	0.325	-0.226	**0.356**	-0.188	**0.369**	0.233	**0.343**	-0.017	-0.107	0.106	-0.026
b*	0.103	-0.198	0.069	-0.051	0.047	-0.177	0.037	-0.267	-0.088	-0.096	0.289
Hue	-0.292	0.004	-0.292	0.135	**-0.361**	**-0.460**	**-0.331**	-0.271	0.012	-0.202	**0.357**
Chroma	0.270	-0.236	0.286	-0.151	0.280	0.102	0.261	-0.113	-0.118	0.042	0.087
% Moisture	-0.178	0.236	0.155	-0.316	0.147	-0.185	-0.045	**-0.402**	-0.045	0.007	-0.028
% Ash	**-0.370**	-0.163	-0.170	0.030	-0.227	-0.035	0.063	-0.071	-0.086	-0.143	-0.008
% Protein	0.026	-0.207	-0.204	0.188	-0.317	-0.027	-0.171	0.169	0.193	-0.093	0.126
% Fat	**0.498**	-0.057	0.200	0.212	0.251	**0.466**	**0.336**	**0.524**	-0.097	0.269	-0.205

Values in bold are different from 0 with a significance level alpha=0.05.

Variables	**pH$_u$**	**% Thaw loss**	**% Cooking loss**	**WBSF**	**SCF - 13th rib**	**SCF - 3rd/4th lumbar**	**L***	**a***	**b***	**Hue**	**Chroma**	**% Moisture**	**% Ash**	**% Protein**	**% Fat**
pH$_u$	**1**														
% Thaw loss	-0.080	**1**													
% Cooking loss	**-0.345**	0.274	**1**												
Warner-Bratzler Shear Force	0.097	-0.092	0.283	**1**											
SCF - 13th rib	**-0.439**	0.061	0.299	-0.254	**1**										
SCF - 3rd/4th lumbar	**-0.437**	0.081	0.262	-0.281	**0.804**	**1**									
L*	0.039	-0.225	-0.027	**0.376**	**-0.448**	**-0.361**	**1**								
a*	0.202	0.127	-0.061	-0.010	0.056	0.135	-0.166	**1**							
b*	0.224	-0.098	0.000	0.180	-0.213	-0.099	**0.532**	**0.632**							
Hue	0.038	-0.297	0.023	0.201	-0.329	-0.241	**0.809**	**-0.417**	**0.436**	**1**					
Chroma	0.225	0.057	-0.045	0.054	-0.036	0.066	0.077	**0.956**	**0.830**	-0.135	**1**				
% Moisture	0.056	-0.249	**-0.697**	-0.051	**-0.389**	**-0.343**	0.293	-0.136	0.098	0.295	-0.057	**1**			
% Ash	**0.374**	0.121	-0.148	-0.069	**-0.353**	-0.297	0.015	-0.248	-0.109	0.159	-0.220	-0.096	**1**		
% Protein	-0.097	0.271	**0.714**	0.156	0.217	0.179	-0.212	-0.009	-0.171	-0.213	-0.075	**-0.935**	0.206	**1**	
% Fat	-0.145	0.099	0.295	-0.133	**0.630**	**0.598**	-0.321	**0.492**	0.120	**-0.426**	**0.397**	**-0.508**	**-0.648**	0.257	**1**

6.4 Discussion

The unimproved nature of the Namaqua Afrikaner was partially reflected by lower weights at weaning compared to purebred Dorper and NA x D crossbred lambs (Tables 6.1). A lower slaughter weight compared to the Dorper was also recorded (Table 6.4). It was also reflected in a reduced dressing percentage in the former breed. The birth weights of the Namaqua Afrikaner did not differ for either of the Dorper or NA x D (Table 6.1). However, these differences have been discussed comprehensively in previous chapters, and will not be elaborated upon here.

It is well known that the Namaqua Afrikaner and other fat-tailed breeds have lower total body fat, with their main depot for storing surplus energy being the fat-tail (Epstein, 1960; Almeida, 2011a; Yousefi *et al.*, 2012). These characteristics, in theory, should give such breeds an advantage in terms of consumer preferences (Kashan *et al.*, 2005); especially since the present day health conscious consumer seems to have a preference for leaner red meat (Higgs, 2000; Webb & O'Neill, 2008; Yousefi *et al.*, 2012). Therefore the drive towards consuming leaner meat, if marketed appropriately, could be advantageous to the meat producer – resulting in less waste when fat is discarded along the production chain, as well as to the end consumer (Kashan *et al.*, 2005).

Apart from the health aspect, the palatability of the meat is also important to consumers, the latter being primarily influenced by fat content. In the consumer's mind there is usually a trade-off effect between the palatability of meat and its fat content (Warriss, 2000a; Webb & O'Neill, 2008; Wood *et al.*, 2008). The fat content not only influences the overall palatability of the meat, but also the rate of *rigor* and thereby physical attributes such as the final pH of the meat, its colour and water holding capacity (Priolo *et al.*, 2001). Fat content specifics, i.e. quantity and composition, can also influence sensory attributes such as aroma, flavour, tenderness and juiciness, thus affecting the overall eating quality of the meat (Warriss, 2000a; Lawrie & Ledward, 2006; Yousefi *et al.*, 2012).

In this study, both Namaqua Afrikaner (146.4 ± 3.11 days) and NA x D (145.8 ± 3.59 days) lambs were slaughtered at a younger chronological age than Dorper lambs (161.5 ± 4.04 days). Based on the results of a similar study done on fat-tailed sheep (Yousefi *et al.*, 2012), it was expected that the overall carcass fatness of the late maturing Namaqua Afrikaner should be less than that of the early maturing Dorper. Although the maximum difference in slaughter age was only ≈16 days, the differences in carcass fatness could possibly be attributed to the fact that the lambs were at different physiological ages (as discussed in detail in the Chapters 2, 4 and 5) (Pállson, 1955; Beitz, 1985; Warriss, 2000b; Irshad *et al.*, 2012). In this study differences in the carcass weights of the Namaqua Afrikaner and both the Dorper and NA x D cross were indicated ($P < 0.001$) (Table 6.4). Furthermore, differences in both the subcutaneous fat (SCF) and intramuscular fat (IMF) depots were also expected as a result of the fat-tailed nature of the Namaqua Afrikaner (Epstein, 1960; Almeida, 2011a; Yousefi *et al.*, 2012). True to expectations measurements of the SCF at the 13th rib clearly showed that the fat depth of the Namaqua Afrikaner was less than both that of the Dorper and NA x D ($P = 0.046$). Unexpectedly no differences were found between the pure breeds and cross breed for fat depth measured at the 3rd and 4th lumbar vertebrae ($P > 0.05$) (Table 6.4) which could possibly be explained by the proximity of the 3rd and 4th lumbar vertebrae to the fat-tail and thus subsequent fat deposition in the rump of Namaqua Afrikaner lambs. It could be argued that, to some extent, surplus energy (fat) intended for the fat-tail depot of the Namaqua Afrikaner lambs was deposited in the subcutaneous fat tissue in the proximal region of the *longissimus lumborum*. According to Almeida (2011b) the fat-tail of the Namaqua Afrikaner has been compared to the hump of a camel. Apart from camels storing surplus energy in their hump as an adaptive trait to desert regions, it is known that during the day camels will position themselves towards the sun at an angle at which the body surface area exposed to radiation is the least (Mukasa-Mugerwa, 1981). Although limited information is available on this topic, it can be postulated that the Namaqua Afrikaner could exhibit similar behaviour and that the thicker fat cover of the dorsal region of the Namaqua Afrikaner could have a similar property, i.e. protection from radiation.

Results as seen for the IMF content (%) were also as expected. The meat of the fat-tailed Namaqua Afrikaner was leaner than that of both the Dorper and NA x D ($P = 0.003$) (Table 6.5). Similarly, Yousefi *et al.* (2012) reported differences in SCF depth measured at the 10th and 11th rib ($P < 0.01$), as well as the IMF content (%) ($P < 0.01$). In another study it was reported that the IMF content of Chall lambs are less compared to a Zel x Chall crossbred genotype (Kashan *et al.*, 2005). It is known that the Dorper has a high IMF content (%) and in research a moderately high heritability estimate (0.48) is reported for IMF content (Jacob & Pethick, 2014; Mortimer *et al.*, 2014), therefore, since the Dorper contributes 50% of the germplasm of the NA x D, a higher IMF content (%) relative to that of the Namaqua Afrikaner was expected (Table 6.4).

6.4.1 Sensory attributes

6.4.1.1 Aroma, flavour and juiciness

No information regarding the sensory profile of the meat of the Namaqua Afrikaner sheep breed could be found in scientific literature. Nonetheless, since the Dorper breed was developed during the 1930's as a result of carcass conformation of the fat-tailed breeds not being acceptable to the British consumer (Nel, 1993; Milne, 2000), it was expected that the flavour and aroma profile of the unimproved Namaqua Afrikaner would not compare favourably with that of Dorper. Additionally, differences were also expected owing to the lower quantity of intramuscular fat (IMF) located in the *longissimus lumborum* (LL) muscle of the Namaqua Afrikaner ($P = 0.003$) (Table 6.5), as well as the possibility of differences in diet between the breeds. Yet, contrary to expectations, DSA did not indicate significant differences between the Namaqua Afrikaner, Dorper and NA x D cross samples for lamb aroma, overall lamb flavour, fatty aroma and both bush-like aroma and flavour ($P > 0.05$) (Table 6.3). In a similar study completed by Yousefi *et al.* (2012) on the meat quality, including the sensory attributes of the Iranian indigenous, fat-tailed Chall and thin-tailed Zel sheep breeds, no significant differences were accordingly observed between these two breeds for either flavour or aroma, thus supporting the results of the current study.

Discriminant analysis (DA) is ideal for indicating similarities or differences between treatments (Næs *et al.*, 2010; Geldenhuys *et al.*, 2014). Although the three treatments did not differ from each other in terms of aroma and flavour attributes as indicated by the ANOVA results, the three treatments could be grouped according to overall sensory profiles (Figure 6.1a). According to the DA plot Namaqua Afrikaner lambs, indicated on the right side of the DA plot (Figure 6.1a), associated more with herbaceous bush-like flavour situated on the right side of the DA variable loadings plot (Fig. 6.1b). To the opposite side, displayed in the left quadrant along F1, both Dorper and the NA x D cross grouped together and showed a closer association with overall lamb flavour, lamb aroma and bush-like aroma (Fig. 6.1b), thus providing a possible explanation for the tendency towards genotypic differences as observed for overall lamb flavour (P = 0.098), as well as bush-like aroma (P = 0.094) (Table 6.3).

According to the principal component analysis (PCA) (Fig. 6.2), as well as the derived Pearson correlation coefficients (r), it can be noted that there was a low, but positive correlation between the sensory attributes lamb aroma and fatty aroma (r = 0.384; P = 0.021) (Table 6.6). There was also a low correlation between bush-like aroma and metallic aftertaste as indicated in the upper-right quadrant of the PCA bi-plot (Fig. 6.2; r = 0.346; P ≤ 0.05). The reason for the latter correlation is not clear.

There were also low to moderate correlations between the aroma and flavour attributes and some of the instrumental variables. The sensory attribute overall lamb flavour and intramuscular fat (IMF) content (%) (r = 0.524; P = 0.001) correlated moderately, as did overall lamb flavour with subcutaneous fat (SCF) depth when measured at both the 13th rib (r = 0.559; P < 0.001) and 3rd and 4th lumbar vertebrae (r = 0.587; P < 0.001) (Table 6.6). Further substantiating these correlations is the higher percentage of IMF found in both the NA x D and Dorper samples compared to the Namaqua Afrikaner (P = 0.003) (Table 6.5), as well as the differences observed in SCF depth measured at the 13th rib (P = 0.046) (Table 6.4). In addition a moderate negative correlation (r = -0.402; P = 0.015) was observed between overall lamb flavour and the moisture content (%) of the samples. This is too be expected as an inverse relationship (r = -0.508; P = 0.002) exists between the IMF content of the meat and its moisture content. Usually, when the IMF content starts to increase, moisture content of the muscle tends to decrease (Strasburg *et al.*, 2008).

Significant positive correlations between the flavour intensity of meat and the quantity of fat present in meat can be found in research (Tshabalala *et al.*, 2003; Hoffman *et al.*, 2009; Watkins *et al.*, 2013). Raw meat does not have a distinctive flavour; flavour is only released upon heat treatment (cooking, roasting, grilling etc.) when volatile compounds are released (Mottram, 1998; Watkins *et al.*, 2013). The intramuscular fat content (quantity and composition), and its distribution, is highly important when it comes to the flavour formation in meat (Melton, 1990; Mottram, 1998; Watkins *et al.*, 2013). Most aroma compounds are lipophilic, they are thus *embedded* in fat (IMF and SCF) and are released during mastication, resulting in the perception of aroma (orthonasal analysis) and flavour (retronasal analysis) (Tshabalala *et al.*, 2003; Watkins *et al.*, 2013). Yet, in the case of leaner meat (lower percentage IMF) the volatile compounds are released faster, i.e. the volatiles are released together with the moisture vapour. This fast tracks aroma perception (Mottram, 1998; Tshabalala *et al.*, 2003).

It is suggested that the adipose tissue in the meat is responsible for the species-specific aromas and flavours (Melton, 1990; Mottram; 1998), while the lean tissue carries the precursors responsible for the meaty flavour, as found in all cooked meats (Melton, 1990; Mottram, 1998).

Early research by Wong *et al.* (1975) established that the primary contributors to the distinctive lamb and mutton flavours were certain volatile, medium length, branched chain fatty acids (BCFA) – particularly 4-methyloctanoic acid (Lindsay, 2008; Tatum *et al.*, 2014). Increased concentrations of these fatty acids are responsible for an increase in intensity of the mutton flavour (Tatum *et al.*, 2014). Young *et al.* (1997) confirmed that 4-methyloctanoic acid, 4-methylnonanoic acid and 4-ethyloctanoic acid are largely responsible for the strong aroma generally characterised as mutton flavour (Warriss, 2000a; Watkins *et al*., 2014). As the lambs grow and mature, an increase in the concentration of the BCFA in the fat tissue is notable (Watkins *et al.*, 2010; Tatum *et al.*, 2014). It is known that BCFA increases with age, becoming more notable as sexual maturity approaches (Sutherland & Ames, 1996; Young *et al.,* 2006). This serves as a plausible explanation for the strong association of the Dorper and NA x D with lamb aroma and overall lamb flavour (Fig. 6.1 & 6.2). Apart from both the Dorper and NA x D meat containing a greater quantity of IMF (P = 0.001), Dorper (161.5 ± 3.44 days) lambs were slaughtered at an older chronological and physiological age than the Namaqua Afrikaner (146.3 ± 3.44 days) and NA x D (145.8 ± 4.54 days) lambs. Furthermore, being an early maturing breed the Dorper lambs could be closer to physiological maturity than the late maturing Namaqua Afrikaner (Pállson, 1955; Beitz, 1985; Warriss, 2000b; Irshad *et al.*, 2012), as discussed in Chapter 3 (Burger *et al.*, 2013) and Chapter 4. Since the lambs used in this study were all castrated males, it could be expected that the concentration of BCFA in the fat of the Dorper ram lambs will be higher than in the Namaqua Afrikaner meat, even though it was not part of the scope of this study to measure BCFA content.

Not only does the composition and fatty acid profile of the meat affect the flavour thereof, but feed consumed by the animal can also affect the final concentration of fat and thus the distribution of saturated and unsaturated fatty acids within the IMF and SCF (Melton, 1990; Vasta & Priolo, 2006; Watkins *et al.*, 2013). Intricate mechanisms are involved through which feed can affect the final flavour profile of lamb meat. Specific plant-derived compounds (phytol, phytene, terpenes and sesquiterpenes) can be transferred directly into the meat (and fat) resulting in specific flavours (Field, 1978; Melton, 1990; Watkins *et al.*, 2013); either directly, should the concentration be high enough or through the formation of new flavour-active compounds via thermal degradation

(Watkins *et al.*, 2013). It is plausible that the strong association of the Namaqua Afrikaner with the herbaceous or so-called bush-like flavour could be attributed to differences in eating preferences of the breeds, as they are known to graze on different grass and forb species (anecdotal data). Therefore the possibility exists that the Namaqua Afrikaner could have grazed on plant species containing stronger flavour precursors than the Dorper and NA x D cross. Nevertheless, it was not part of the scope of this study to determine the different diet preferences of these breeds and information in literature regarding diet was not available for the Namaqua Afrikaner. It could also be argued that, with the Namaqua Afrikaner meat being leaner ($P = 0.003$), the bush-like flavour becomes more apparent, i.e. it is not masked by the overall lamb flavour.

The volatile and non-volatile components of meat are not solely responsible for the perception of flavour. Other attributes including tenderness, resistance during chewing, juiciness, the structure and breakdown of the muscle can either directly affect, temper or offset the overall flavour perceived by the consumer (Watkins *et al.*, 2013), as can be seen from the significant correlations between overall lamb flavour and several of the textural attributes (Table 6.6).

A low correlation was observed between overall lamb flavour and initial juiciness ($r = 0.367$; $P = 0.028$), while a moderate correlation existed between overall lamb flavour and sustained juiciness ($r = 0.469$; $P = 0.002$). Juiciness can be regarded as an indicator of the moisture content (%) of meat (Table 6.5) (Geldenhuys *et al.*, 2014). Initial juiciness is detected in the rapid release of meat fluids during mastication (or when pressed between thumb and forefinger), while sustained juiciness is observed through the stimulation of saliva secretion during mastication (Warriss, 2000a; Lawrie & Ledward, 2006). Nonetheless, the results of this study were inconclusive regarding the relationship between juiciness and moisture content of the meat as no significant correlations ($P > 0.05$) were observed between these attributes (Table 6.6). However, a low correlation existed between sustained juiciness and IMF content (%) ($r = 0.336$; $P = 0.045$) (Table 6.5), indicating that a higher IMF content could result in a higher degree of sustained juiciness (Warriss, 2000a).

As mentioned, no information is available on the sensory profile of Namaqua Afrikaner sheep, but several conclusions can be drawn from what is known about this breed. It was expected, i.e. attributable to its lower IMF content (%) ($P = 0.003$), that the meat of the Namaqua Afrikaner would *not compare* favourably with Dorper in terms of sustained juiciness (Table 6.3). Despite the significant differences in IMF ($P = 0.003$) (Table 6.5), no significant differences were detected between the Namaqua Afrikaner, Dorper or NA x D cross for initial or sustained juiciness ($P = 0.161$) (Table 6.3). However, when viewing the PCA bi-plot (Fig. 6.2), there seems to be some association of both the Dorper and NA x D cross with initial and sustained juiciness, as well as fat content. Nonetheless, the only correlation that was significant, is that of IMF content (fat content) with sustained juiciness ($r = 0.336$; $P \leq 0.05$), again indicating that the higher fat content adds to juiciness. This is not the case for Namaqua Afrikaner which reflected a smaller association with juiciness attributes (Fig. 6.2). The latter tendency could be as a result of the significantly lower fat content of the Namaqua Afrikaner breed (Table 6.5).

6.4.1.2 Sensory tenderness, residue and instrumental tenderness

The DA analysis (Fig. 6.1) indicated that the grouping of Dorper and the NA x D cross on the left side, and Namaqua Afrikaner on the right side of the DA plot can be attributed to the difference in sensory tenderness. The term *tenderness* refers to *texture*, a physical characteristic which encompasses hardness, springiness, chewiness, cohesiveness and even juiciness of meat (Solomon *et al.*, 2011). Unfortunately, tenderness is one of the most varying attributes of meat, and it can be affected by a range of extrinsic and intrinsic variables, singly or in combination (Destefanis *et al.*, 2008). Sensory tenderness, as analysed in the current study, focused mainly on first bite, which translates to the ease of biting through the meat during the first two to three chews and residue, indicating the aggregate of sample still left in the mouth after mastication (20-30 chews) (Table 6.2). Tenderness (first bite) was the only sensory attribute where differences between the two pure breeds and the crossbred genotype were observed by the trained sensory panel. Meat from the Namaqua Afrikaner scored the lowest for tenderness, i.e. the least tender meat, while the meat from both Dorper and NA x D scored the highest for tenderness (Table 6.3). Similar results were reported in the study by Yousefi *et al*. (2012), where the indigenous fat-tailed Chall breed also had less tender meat than the thin-tailed Zel breed ($P < 0.001$).

In this study it has already been indicated that a higher IMF content results in an increased perception of sustained juiciness (Fig. 6.2; Table 6.6). The question is whether there is a correlation between juiciness and sensory tenderness (Warriss, 2000a), and specifically between IMF and tenderness. Some researchers argue that juiciness and sensory tenderness are interrelated; the one affects the other (Miller, 2004). It has been reported that meat with a higher IMF content, and thus a higher degree of juiciness, can be perceived as being more tender than meat with a lower IMF content, i.e. even though no differences in Warner-Bratzler shear force were reported (Warriss, 2000a). This argument is substantiated by the strong positive correlation between sensory tenderness and sustained juiciness ($r = 0.807$; $P < 0.001$) (Table 6.6), as well as the correlation between tenderness and IMF content ($r = 0.466$; $P = 0.004$) (Table 6.6). Studies have shown that IMF has a diluting effect on the perimysial collagen, consequently as the IMF content in the meat increases it could result in more tender meat (Schönfeldt, 1993; Warriss, 2000a; Warner, 2010; Yousefi *et al.*, 2012).

Another reasonably strong correlation was observed between tenderness and overall lamb flavour ($r = 0.686$; $P < 0.001$) (Table 6.6). As discussed, a moderate correlation between IMF content and overall lamb flavour ($r = 0.524$; $P < 0.001$) existed, therefore it could be postulated that the strong correlation between sensory tenderness and overall lamb flavour could be as a result of the IMF content.

From the results it can further be gathered that sensory tenderness (first bite) shows a highly negative correlation with residue (r = -0.710; P < 0.001) (Table 6.6; Fig 6.2), demonstrating that the easier the mastication of the meat is, the less residue will be left in the mouth before swallowing. Surprisingly, however, no significant differences were observed by the panel for residue (P = 0.564) or for in the instrumental tenderness (shear force) (P = 0.108) measured according to the WBSF (Tables 6.3 & 6.4). No differences in shear force were accordingly observed in Chapter 5. However, there seemed to be a moderate correlation between residue, the sensory attribute, and WBSF (r = 0.587; P < 0.05) (Table 6.6; Figure 6.2). It can be argued that this correlation is an indication of the lower sensory tenderness score for Namaqua Afrikaner being linked to WBSF, as well as the sensory attribute, residue (Schönfeldt, 1993; Warriss, 2000a; Warner, 2010).

6.4.2 Physical attributes

Differences where observed in the pH_u (P = 0.023) of the samples, with the NA x D cross (5.63 ± 0.05) attaining the lowest pH_u (Table 6.4). The pH_u of the Namaqua Afrikaner (5.83 ± 0.04) was the highest in absolute terms but it was still on the upper limit of the normal pH_u range (5.3 to 5.8) (Honikel, 2004a). According to Silva *et al.* (1999) pH 5.8 should be regarded as moderate DFD (normal = pH 5.5 to 5.8; moderate DFD = $5.8 < pH < 6.2$ and DFD = pH 6.2 to 6.7). With a high pH_u the moisture inside the muscle is tightly bound, resulting in less water lost during cooking (Warriss, 2000a). This contention was supported by the inverse correlation between percentage cooking loss and pH_u (r = -0.345; P = 0.039). Although IMF acts in an insulating capacity by surrounding the myofibrils and subsequently lowering the amount of water lost during cooking, as seen with the Dorper and NA x D cross (Yousefi *et al.*, 2012), it can be argued that the higher moisture content (%) of the Namaqua Afrikaner meat could counteract the effect of a lower IMF content (%), thus accounting for the fact that no differences in percentage cooking loss were observed (P = 0.545) (Table 6.4).

In addition, low negative correlations between pH_u and SCF cover at both the 13th rib (r = -0.439; P < 0.001) and 3rd/4th lumbar vertebrae (r = -0.437; P < 0.001) were illustrated (Table 6.6). The lower and less uniform fat cover of the Namaqua Afrikaner could result in the carcasses cooling at a quicker rate *post mortem*. It has been shown that a carcass with a thicker SCF layer will cool at a slower rate as a result of the SCF layer having an insulating effect on the carcass. This will result in a faster and further decline in pH and in the end a lower pH_u and possibly more tender meat (Priolo *et al.*, 2001).

The wild and flighty nature of the Namaqua Afrikaner (anecdotal data, supported by preliminary results from Cloete *et al.*, 2013) could also influence the glycolytic potential of the meat *post mortem.* A certain amount of *ante mortem* stress is expected during transport and lairage and animals not used to human-intervention will be more subjected to stress and the resultant depletion of glycogen reserves, which ultimately result in a higher pH_u (Priolo *et al.*, 2001; Honikel, 2004b; Cloete *et al.*, 2005)

Generally, when purchasing meat, consumers expect the colour of the meat to be bright red; i.e. the colour of oxymyoglobin (Lawrie & Ledward, 2006). Differences were observed for both the a* and L* values. The a* value is indicative of the red/greenness of the sample, while the L* value indicates the lightness of the meat, with a higher value indicating a lighter colour (Table 6.4). The meat of the Namaqua Afrikaner had a lower a* value, thus less red, and a higher L* value, thus lighter or paler in appearance ($P < 0.001$). A positive correlation is observed between the a* value (redness) and IMF content (%) ($r = 0.492$; $P = 0.002$). It has been reported that a greater IMF content could influence the colour of the meat as a result of the increasing oxidative instability due to the increased IMF content (Renerre, 1986; as cited by Yousefi *et al.*, 2012; Sañudo *et al.*, 1998; Vergara *et al.*, 1999). Animals with a greater carcass fat content therefore require an increased myoglobin content to sustain the increased demand for oxygen and thus resulting in a more vivid red colour (Renerre, 1986; as cited by Yousefi *et al.*, 2012).

6.5 Conclusions

The main aim of the study was to determine the sensory profile of the indigenous fat-tailed Namaqua Afrikaner sheep through the process of descriptive sensory analysis. Through the reported results it was illustrated that the aroma and flavour attributes of the Namaqua Afrikaner were similar to that of the Dorper, as well as a Namaqua Afrikaner x Dorper cross included in the study. The greatest difference was observed in the sensory tenderness, where the meat of the Namaqua Afrikaner was adjudicated by the trained taste panel to be less tender, most probably as a result of lower IMF values associated with this indigenous, unimproved breed. Although the meat of the Namaqua Afrikaner is regarded as being less tender, its lower intramuscular fat content (%) can be promoted as desirable, especially with consumers demanding leaner meat. Finally, the results this study can be used as baseline data for future studies on the Namaqua Afrikaner and other indigenous fat-tailed breeds.

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CHAPTER 7

General conclusions and recommendations

7.1 Introduction

Factors such as global warming, coupled with a marked growth in the world population (OECD/FAO, 2012; OECD/FAO, 2013; OECD/FAO, 2014), could result in a loss of the quality and quantity of natural forage for livestock, as well as crops produced for animal feed (Smith *et al.*, 1996; Rust & Rust, 2013). In South Africa the majority (80%) of the agricultural land is already located in arid or semi-arid regions unsuitable for cropping (Cloete & Olivier, 2010). Livestock kept in extensive farming systems are known to be affected by changes in weather, ultimately influencing their growth and reproduction abilities (Rust & Rust, 2013). With the agricultural sector facing numerous challenges in having to increase meat production, while keeping input resources the same, researchers are busy investigating the possibilities of farming with indigenous breeds as a possible solution (FAO, 2003; OECD/FAO, 2012; Gerber *et al.*, 2013; OECD/FAO, 2013; Montossi *et al.*, 2013). Indigenous breeds are presumably adapted to their natural habitat, i.e. the prevailing climate, forage species as well as the predominant stressors, such as parasites and diseases (FAO, 2003; Niang *et al*., 2014).

In order to be able to manage the agricultural pressures exacerbated by climate change, it is predicted that livestock farmers in Southern Africa will opt to change to livestock species better adapted to withstand these environmental pressures and changes, i.e. small ruminant species (Seo & Mendelsohn, 2008; Rust & Rust, 2013). The fat-tailed, late maturing *Namaqua Afrikaner* is one such sheep breed (*Ovis aries)*; being indigenous to South Africa (Epstein, 1960; Snyman *et al.* 1993; FAO, 2000; ARC, 2013). The most prominent feature of the Namaqua Afrikaner is its fat-tail, an adaptive trait to the harsh regions (Epstein, 1960). During times of forage abundance surplus fat is stored in the fat-tail, instead of a thick subcutaneous fat (SCF) layer, as seen with the imported European and developed composite breeds. In contrast, the Namaqua Afrikaner stores surplus energy in the fat-tail (Lawrie & Ledward, 2006). The Namaqua Afrikaner is adapted to survive on a lower plane of nutrition and its longer legs enables it to travel vast distances to find sufficient quantities of nutritious forage (Epstein, 1960; Hugo, 1966; Epstein, 1971; Ramsay *et al.,* 2001; Lawrie & Ledward, 2006). Even though this breed is unimproved and considered to have a wild and “flighty” temperament, the Namaqua Afrikaner is also believed to have a greater immunity against diseases and parasites.

At present the *early maturing* Dorper is South Africa’s main meat breed and is considered to have good meat quality and carcass characteristics. However, a disadvantage of the Dorper, as a result of its early maturing nature, is that it can easily become too fat. The *late maturing* South African Mutton Merino (SAMM) is the main dual-purpose breed farmed with in South Africa, and its carcass usually contains less fat when slaughtered at the same chronological age (Webb and Casey, 1995; Milne, 2000; Cloete *et al.*, 2007). Snyman *et al*. (1996) reported that while the monetary yield on Namaqua Afrikaner carcasses might be smaller than that of the commercial South African breeds, the Namaqua Afrikaner could outperform the latter South African breeds under severe droughts.

Due to the fact that limited information regarding the meat quality and carcass yield of the Namaqua Afrikaner is available, the main objective of this study was to investigate and compare the Namaqua Afrikaner to the purebred Dorper and SAMM, as well as two crossbred genotypes, namely the Namaqua Afrikaner x Dorper (NA x D) and the SAMM x Dorper (SAMM x D) in terms of following:

1) Carcass composition, i.e. the ratio in which the main tissues (muscle, bone, fat) can be found in the carcass. Wholesale cuts (leg, loin, rib, shoulder) of Namaqua Afrikaner lambs were compared with those of the Dorper and SAMM contemporaries at an average age of 5 months. Data were sourced during the 2010 production year. The study was repeated with hoggets (average 16 months old), but only Dorper hoggets were compared to the Namaqua Afrikaner. For this part of the study data was obtained from the 2012 production year.
2) Carcass characteristics (birth weight, weaning weight, slaughter weight and dressing percentage), physical meat quality attributes (pH, subcutaneous fat (SCF) depth measured at both the 13th rib and 3rd/4th lumbar vertebrae, percentage drip loss, percentage cooking loss, instrumental tenderness and colour) and proximate composition (percentage moisture, protein, fat and ash content) of the Namaqua Afrikaner breed were compared with that of the purebred Dorper and SAMM and the two crossbred genotypes (NA x D and SAMM x D). *Longissimus et lumborum* samples were collected over a three year period, running from 2010 to 2012.
3) The sensory profile (aroma, flavour, tenderness and juiciness), physical meat quality attributes (pH, subcutaneous fat depth measured at both the 13th rib and 3rd/4th lumbar vertebrae, percentage drip loss, percentage cooking loss, instrumental tenderness and colour) and proximate composition (percentage moisture, protein, fat and ash content) of the *longissimus et lumborum* of Namaqua Afrikaner, Dorper and the Namaqua Afrikaner x Dorper cross ram lambs were compared. Data was sourced during the 2010 production year.

As mentioned, the majority of the samples were collected over a three year period (2010-2012). Although the physical attributes were measured upon collection of the samples, the proximate composition of all the samples were done during 2012-2013, as well as the sensory analyses and all the statistical analyses.

A further aim of this study was to develop base-line information for the Namaqua Afrikaner, as well as the Namaqua Afrikaner x Dorper cross, a vital prerequisite for future meat science studies.

In view of the above, the focus of this chapter is to discuss, in general terms, how the Namaqua Afrikaner differs from the respective breeds in terms of carcass composition and lean meat yield, general carcass characteristics, as well as physical meat quality characteristics, proximate composition and sensory profile of meat obtained from the *longissimus et lumborum* (LL) muscle.

7.2 Main findings

7.2.1 Carcass composition and lean meat yield of Namaqua Afrikaner, Dorper and SAMM

Climate change may constrain the contribution of commercial sheep breeds such as the Dorper and SAMM in future, as constraints on food sources may limit growth and development of animals, especially when not adapted to harsh conditions.

At five months of age, the unimproved, late maturing Namaqua Afrikaner did not compare well with the early maturing Dorper in terms of meat yield. Nevertheless, despite its carcass being smaller and containing a higher percentage of bone than the average SAMM carcass, it performed better against the SAMM in terms of meat yield, with which breed differences were only observed in the expensive loin cut. Although the Namaqua Afrikaner carcass contained significantly more bone, it contained less fat than the other two breeds. This is a beneficial trait in terms of a health perspective. Consumer preferences are changing towards food products beneficial to health, lean meat is sought after and this creates the possibility of marketing the leaner meat of the Namaqua Afrikaner.

At an older chronological (and physiological) age, the Namaqua Afrikaner carcass compared more favourably against that of the Dorper. The lean meat of the Namaqua Afrikaner was confirmed as a positive attribute, with consumer preferences favouring the consumption of lean red meat. Although its higher bone yield still counts against the Namaqua Afrikaner, it compared well with the Dorper in terms of meat yield at this stage. As a result future research on crossbreeding with the Namaqua Afrikaner could elucidate the possibility of combining the important attributes of the Namaqua Afrikaner, such as its hardiness, with the meat producing qualities of the Dorper.

7.2.2 Carcass characteristics of Namaqua Afrikaner, Dorper, SAMM, NA x D and SAMM x D

The experimental research site situated in the West Coast Strandveld, South Africa is expected to receive an annual rainfall of 221 mm. Deviations from this were recorded over the three years, and notably during 2011 (118 mm) the precipitation was only half of what was reported in 2010 (237 mm). Precipitation in 2012 was intermediate at 159 mm. Consequently the quantity and quality of the natural grazing varied over the three years, resulting in changes in the plane of nutrition over the course of the study.

The main aim of this section of the study was to determine how the carcass characteristics, physical meat quality attributes and proximate composition the indigenous, fat-tailed Namaqua Afrikaner and its crossbred genotype (NA x D) compared with that of the commercial meat breeds (Dorper and SAMM) and their crossbred genotype (SAMM x D). Breed differences were observed for all of the carcass characteristics measured: birth, weaning and carcass weights, as well as dressing percentage. The birth weight of the Namaqua Afrikaner compared favourably with the pure breeds, but both crossbred genotypes produced heavier lambs. The unimproved and late maturing nature of the Namaqua Afrikaner was clearly visible in the lower weaning and slaughter weights reported, as well as dressing percentage. The only favourable comparison in terms of dressing percentage was seen with the carcasses of SAMM, also late maturing. The NA x D compared well with the Dorper, SAMM and SAMM x D for all of the carcass characteristics. As expected, production year also had an influence on dressing percentage results, with the means recorded during 2011 being the lowest.

Differences as a result of breed were also recorded for the physical meat quality attributes of the LL. The Namaqua Afrikaner meat had both a high pH_{45} and pH_u, but even though the pH_u was high, it still compared favourably with that of the Dorper and SAMM. Conversely, while the NA x D cross LL also had a high pH_{45}, a low pH_u was attained in this genotype. Another interesting observation was that while, as expected, the SCF depth at the 13th rib of the Namaqua Afrikaner was the lowest in absolute terms, measured at the 3rd/4th lumbar vertebrae its SCF depth was thicker than that of the SAMM. The overall profile of the physical attributes of the meat from Namaqua Afrikaner lambs was similar to that of the SAMM, comparing well with this dual-purpose breed. NA x D compared well with the Dorper for both physical attributes and proximate composition, providing the opportunity for future research to investigate the meat quality of terminal crossbred progeny from Namaqua Afrikaner sires. It is interesting to note that South Africa's most recent sheep breed, the Meatmaster, originated from a cross between the Dorper and another indigenous fat-tailed breed, the Damara (Peters *et al*., 2010). Therefore it can be argued that the possibilities of crossbreeding with fat-tailed, indigenous breeds are viable and should be further investigated. The Namaqua Afrikaner lambs contained the least amount of fat. This is regarded as a positive attribute and if marketed correctly could enhance the commercial profile of this breed. Probably the most important finding of this section was that the meat of the Namaqua Afrikaner compared well in terms of shear force (instrumental tenderness) with the other breeds/crosses. This could imply that its meat should not be less tender than that of the other breeds when analysed for sensory tenderness.

7.2.3 Sensory profile, physical meat quality attributes and proximate composition of Namaqua Afrikaner, Dorper and NA x D ram lambs

The main aim of this section of the study was to determine the full sensory profile of the indigenous fat-tailed Namaqua Afrikaner breed using descriptive sensory analysis. The results illustrated that the aroma and flavour attributes of the Namaqua Afrikaner were similar to that of the Dorper, as well as the NA x D cross. It is well known that fat content enhances aroma and flavour in meat and the fact that the Namaqua Afrikaner, with its significantly lower fat content, resulted in a comparable aroma and flavour profile as that of the other two breeds can be regarded as a valuable output. The results also indicated, as already shown in the previous section, that the three breeds were similar in terms of instrumental tenderness. There was, however, a significant difference in sensory tenderness: The result was not expected – as indicated in Section 7.2.2, the respective breeds did not differ significantly in terms of instrumental tenderness. This is most probably as a result of lower IMF values associated with the Namaqua Afrikaner. Although the meat of the Namaqua Afrikaner is regarded as being less tender, it has a favourable aroma and flavour profile, similar to that of Dorper, as well as the NA x D cross. This result, and the fact that this indigenous breed has a significantly lower intramuscular fat content (%), can be used to market the Namaqua Afrikaner amongst health conscious consumers. Finally, the results of this study can be used as baseline data for future studies on the Namaqua Afrikaner and other indigenous fat-tailed breeds.

7.3 Recommendations for future research

As already indicated, the current research can be expanded to further elucidate differences between the respected breeds tested in this study. There are also other possibilities for further research. Extensive investigation into the fatty acid profile of the Namaqua Afrikaner and NA x D should be done. Anecdotal reports have shown that the latter breeds tend to have a higher polyunsaturated fatty acid (PUFA) to saturated fatty acid (SFA) ratio (P:S ratio) than the Dorper and SAMM. Yousefi *et al.* (2012) recently published results on a study done on the indigenous fat-tailed Chall and thin-tailed Zel sheep of Iran. Results on the *longissimus thoracis et lumborum* samples indicated that the Chall lambs had a significantly lower intramuscular fat concentration than the Zel lambs ($P < 0.01$). Furthermore the Chall lambs contained significantly more myristic (C14:0; $P < 0.001$), linolenic (C18:3n3; $P < 0.01$), arachidic (C20:0), arachidonic (C20:4n6; $P < 0.05$) and docosahexaenoic acids (C22:6n3; $P < 0.001$) when compared to Zel lambs, thus adding significantly to the PUFA profile of the Chall lambs. The recommended dietary ratio for n6:n3 PUFA should ideally be smaller than 4.0, while it is advised that the P:S ratio should be greater than 0.4 (Wood *et al*., 2008). It has been shown that with a reduction in intramuscular fat (IMF), the ratio of P:S increases (Strasburg *et al.*, 2008; Webb & O'Neill, 2008). Therefore, having less fat stored in intramuscular fat (IMF) depot's (Epstein, 1960; Almeida, 2011; Yousefi *et al.*, 2012), the Namaqua Afrikaner could possibly have a more beneficial P:S ratio. This aspect should be substantiated with research of the fatty acid profile of the Namaqua Afrikaner.

In addition, research on the consumer acceptability of the meat of the Namaqua Afrikaner and NA x D should be done. If the lean meat of the Namaqua Afrikaner is marketed appropriately (i.e. as lean meat and thus potentially beneficial to health), health conscious consumers might prefer this meat despite it being less tender. It might also be advisable to further investigate the sensory tenderness profile of the Namaqua Afrikaner, as well as the NA x D, using a larger sample size to include the effect of gender.

Future research should be conducted on more balanced samples in terms of gender. The slaughtering of ewe lambs in the present study was constrained in some genotypes, because of the need of female replacements in the breeding flock, making it impossible to accurately quantify sex effects in the resource population.

This study has shown that meat from Namaqua Afrikaner sheep is leaner than that of the Dorper (as main meat breed), while it was mostly acceptable from a sensory perspective. There is thus no evidence that consumers will discriminate against Namaqua Afrikaner meat based on the traits studied. Studies on other traits of economic importance are indicated since it is accepted that adapted breeds like the Namaqua Afrikaner may hold advantages in fitness and robustness traits in comparison to commercial breeds partially or wholly from European origin.

Finally, the recommended further research will definitely add significantly to the current baseline data on the Namaqua Afrikaner. An expanded data set, especially on the fatty acid profile, will also be most invaluable for the expansion of the South African food composition tables of the South African Medical Council.

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