Growth performance, carcass characteristics and meat quality of Nguni, Bonsmara and Angus steers raised on natural pasture

By

Voster Muchenje

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Department of Livestock and Pasture Science

School of Agriculture and Agribusiness

Faculty of Science and Agriculture

University of Fort Hare

Alice

Republic of South Africa

Promoter: **Professor K. Dzama**

Co-promoter: **Professor M. Chimonyo**

Associate Promoter**: Dr P. E. Strydom**

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Declaration

I, Voster Muchenje, hereby declare that this work has not previously been submitted at this or any other university, and that it is my own work in design and execution and that all reference materials contained therein have been duly acknowledged.

Abstract

Growth performance, carcass characteristics and meat quality of Nguni, Bonsmara and Angus steers raised on natural pasture

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The objective of the current study was to compare tick loads, growth, carcass characteristics and meat quality of Nguni, Bonsmara and Angus steers raised on natural pasture. A total of 30, 7-month old steers each of Bonsmara and Angus, and 40 Nguni steers were kept at the University of Fort Hare Farm till slaughter at 18 months. Monthly weights of the steers were recorded. Carcasses were electrically stimulated. The *m. longissimus thoracis et lumborum* was sampled for the measurement of meat colour, pH, drip loss, sarcomere length (SL), water holding capacity (WHC), cooking losses, myofibrillar fragmentation length (MFL), Warner Bratzler shear force (WBSF), fatty acid profiles and sensory characteristics of the steers. Urine samples were collected at the slaughter line for the determination of stress hormone concentrations.

The Nguni had the lowest tick load ($P < 0.05$) while the Angus had the highest tick load ($P < 0.05$). Tick load did not affect the growth rate and carcass characteristics of the steers. Bonsmara and Angus steers had higher ($P < 0.05$) carcass weight and dressing percentage than the Nguni steers. Meat quality characteristics were similar ($P > 0.05$) among all the breeds, except that Nguni meat was darker (L*) ($P < 0.05$) than meat from

the other two breeds. The Bonsmara had the highest ($P > 0.05$) concentrations while the Nguni had the lowest ($P > 0.05$) concentrations of stress hormones. There were significant ($P < 0.05$) correlations between WB values of meat aged for two and 21 days in Nguni and Bonsmara, but not in Angus. The correlations among stress responsiveness hormones and meat quality were breed-dependent.

Except monounsaturated fatty acids (MUFA) and the n-6/n-3 ratio, fatty acid profiles among the breeds were similar ($P > 0.05$). Cholesterol levels among the breeds were similar ($P > 0.05$). The Nguni had the best ($P < 0.05$) sensory characteristics, such as flavour and tenderness. It can be concluded that while the Nguni is a small framed breed, its meat quality is similar to that of Bonsmara and Angus and has the best meat taste when raised on natural pasture.

Keywords: Catecholamines, cholesterol, dressing percentage, fatty acids, flavour, meat tenderness, natural meat

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CHAPTER 1: Introduction

Beef production is a highly competitive industry such that it is imperative that all factors affecting its profitability, growth and sustainability should be given enough consideration. Rearing indigenous beef cattle breeds, such as the Nguni, on natural pasture without dietary supplementation, in communal areas is a common feature in developing countries (Bester, Matjuda, Rust, & Fourie, 2001). The need for meat from the indigenous Nguni cattle to compete in the market underscores the necessity to assess their meat production potential in relation to established beef breeds. Given that most communal and small-scale farmers use natural grazing without dietary supplementation, such evaluations should be done on natural pasture.

Communal grazing involves the grazing of cattle from different households on the same piece of land (Bester *et al*., 2001). There is limited livestock and rangeland management principles applied resulting in rangeland deterioration and poor livestock conditions. Although feed quantity and quality is adequate during the rainy season, biomass yield declines during the dry season, resulting in cattle losing liveweight (Bester *et al*., 2001). Instead of supplementing the animals, farmers sometimes sell their animals for slaughter before marked weight losses begin. Despite these possible limitations, modern consumers are increasingly concerned about production of safe meat with no undesirable effects on their health (Andersen, Oksbjerg, Young, & Therkildsen, 2005). This results in an increased preference for naturally or organically produced meat. Furthermore, the promotion of Nguni beef production in rural areas can increase off-take and reduce beef imports in South Africa where local meat supply cannot meet the demand for meat products.

Organic meat production entails the little or minimal use of chemicals in cattle management activities such as tick control. A considerable amount of work on tick infestation and meat production has been conducted on cultivated pastures and in feedlots (Gertenbach & Henning, 1995; Collins-Luswet, 2000). Very little, if any, has been done under natural grazing conditions, as is commonly practised in the communal areas. Furthermore, most studies in South Africa on ticks (Spickett, De Klerk, Enslin, & Scholtz, 1989; Webb & David, 2002; Schwalbach, Greyling, & David, 2003), growth and meat production (Collins-Luswet, 2000; Strydom, Naude, Smith, Scholtz, & van Wyk, 2000; 2001) covered these aspects separately yet ticks have been reported to affect animal productivity (Scholtz, Spickett, Lombard, & Enslin, 1991; Johnsson, 2006; Kivaria, 2006) and ultimately meat production. These studies left out animal welfare, especially during transportation, handling at loading, off-loading and at the abattoir, and its effects on meat quality.

Although they are a small to medium sized breed, the indigenous Nguni cattle of South Africa are reported to be adapted to harsh environments (Collins-Luswet, 2000). The Nguni breed is increasingly attracting international interest, mainly due to its resilience to tick-borne diseases, high reproductive performance, good walking and foraging ability, and low maintenance requirements, acquired through centuries of natural selection (Schoeman, 1989; Strydom *et al*., 2001). The Nguni Society of South Africa discourages the dipping of the Nguni cattle because the breed has tick immunity acquired over years (Hobbs, 2005). The Nguni can, therefore, play a significant role in the production of high value organic beef because it needs little, if any, chemical tick control. The Bonsmara, a synthetic South African breed with 3/16 Hereford, 3/16 Shorthorn, and

5/8 Afrikaner (Porter, 1991), is a hardy, heat resistant beef producer. The Bonsmara competes favourably with European beef cattle while withstanding subtropical conditions, such as high temperatures, ticks and most tick-borne illnesses (Spickett *et al*., 1989). They are well muscled with high meat yield and quality. It is important, therefore, to compare the performance and meat quality to the Nguni breed. However, they are not as well adapted to harsh conditions as the Nguni breed. The Angus is a Scottish breed with desirable meat related characteristics, such as early maturity and marbling. It is susceptible to ticks and tick-borne diseases. However, no studies have been done on tick tolerance, growth, carcass characteristics, pre-slaughter animal welfare and meat quality of these cattle breeds under communal grazing systems in rural areas.

1.1. Justification

The promotion of indigenous cattle breeds suchs as the Nguni, with the intention of identifying niche markets for organic Nguni beef, makes it imperative to evaluate the growth performance, carcass characteristics, animal welfare and response to stress at the abattoir and meat quality. With more red meat consumers becoming health conscious, there is scope in studying the fatty acid profiles of naturally beef since some fats affect the health of meat consumers. Identification of alternative ways to reduce tickloads in cattle is necessitated by the appeal to eliminate the use of chemicals in organic beef production. Such methods include the use of adaptable indigenous breeds, such as the Nguni.

1.2. Objectives

The broad objective of the current study was to assess the growth performance, tick loads, carcass characteristics and the meat quality of the Nguni, Bonsmara and Angus steers reared on natural pasture. The specific objectives were:

1. To compare tick loads, postweaning growth performance and carcass characteristics of dipped and non-dipped Nguni, Bonsmara and Angus steers raised on natural pasture;
2. To assess stress responsiveness and its effect on meat from Nguni, Bonsmara and Angus steers raised on natural pasture;
3. To determine within-breed relationships among meat quality traits of Nguni, Bonsmara and Angus steers raised on natural pasture;
4. To evaluate the meat quality and fatty acid profiles of Nguni, Bonsmara and Angus steers raised on natural pasture; and
5. To compare the sensory evaluation of Nguni, Bonsmara and Angus steers raised on natural pasture.

1.3. Hypotheses

It was hypothesised that Nguni beef produced under natural conditions is similar to that of established beef breeds raised under similar conditions. In addition, there are relationships among stress responsiveness and meat quality characteristics that can be used to improve meat production. The specific hypotheses tested were:

1. There are no differences in tick loads, postweaning growth performance and carcass characteristics of dipped and non-dipped Nguni, Bonsmara and Angus steers raised on natural pasture;
2. There are within-breed relationships between stress hormonal concentrations and the quality characteristics of meat from Nguni, Bonsmara and Angus steers raised on natural pasture;
3. There are within-breed relationships among meat quality traits of Nguni, Bonsmara and Angus steers raised on natural pasture;
4. There are no differences in meat quality and fatty acid profiles of Nguni, Bonsmara and Angus steers raised on natural pasture; and
5. There are no differences in the sensory characteristics of Nguni, Bonsmara and Angus steers raised on natural pasture.

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CHAPTER 2: Literature review

(Submitted to *Food Chemistry*)

2.1. Introduction

Production of beef on natural grazing without dietary supplementation and use of acaricides requires the use of cattle breeds that can tolerate harsh conditions. The Nguni cattle breed provides an opportunity for natural meat production because of its adaptability to harsh conditions. A considerable amount of work on tick infestation and meat production has been conducted on cultivated pastures and in feedlots. Unfortunately, very little, if any, has been done on tick infestation, growth, stress responsiveness and meat production of the Nguni under natural grazing conditions, as is commonly practised in the communal areas. Despite there being a possible relationship among tick loads, growth and meat production, these parameters have been covered separately on feedlots (Gertenbach & Henning, 1995; Collins-Luswet, 2000). This review, therefore, focuses on breed differences on tick tolerance, growth, carcass characteristics, stress responsiveness and meat quality.

2.2. Importance of ticks in relation to animal productive performance

Ticks are vectors of tick-borne diseases, cause tick-worry and may affect cattle productivity. Body weight losses of between 0.6 g and 63 g per engorged female tick were reported and acaricide-treated animals gained more weight than those left untreated (Mattioli, Pandey, Murray, & Fitzpatrick, 2000; Scholtz, 2005; Johnsson, 2006).

However, Norval, Sutherst, Kurki, Gibson and Keer (1988) reported no weight losses in Sanga cattle with tick infestation. Scholtz *et al*. (1991) reported no differences in weaning weight between dipped and undipped Nguni cattle. The sucking of blood may deprive some tissues of nutrients and oxygen or affect deposition of intramuscular fat (IMF). Protein deposition requires energy and this may be disturbed by the reduction of oxygen supplied to the tissues due to blood sucking by the ticks. Tick effects on animals depend on their abundance. The ticks breed and survive when rainfall (Schwalbach *et al*., 2003; Wesonga, Orinda, Ngae, & Grootenhuis, 2006), humidity and ambient temperatures are high (Webb & David, 2002; Zeleke & Bekele, 2004). Ticks prefer warm and moist predilection sites (Webb & David, 2002) that also provide protection from the environment and predation from birds. Knowledge of tick distribution and the factors affecting them is important in designing tick control measures.

Tick control using acaricides is costly and may result in some ticks developing resistance to acaricides. Alternative approaches, such as the use of adapted indigenous cattle breeds (Meltzer, 1996), are recommended. The Nguni cattle breed of South Africa is such a breed that can be used for beef production with minimal dipping. The Nguni has got tick immunity it acquired over the years (Spickett *et al*., 1989). With its ability to survive on natural grazing and immunity to tick-borne diseases the Nguni, has a potential of producing high value organic beef. Indigenous cattle breeds have low tick loads because of their abilities to respond immunologically to tick infestation (Mattioli *et al*., 2000; Das, Gosh, & Ray, 2005; Johnsson, 2006) and having short and shiny hair. Spickett *et al*. (1989) and Scholtz *et al*. (1991) reported differences in tick resistance between Hereford, Bonsmara and Nguni cattle, with the Nguni having the fewest ticks. Webb and

David (2002) reported similar findings, where Tswana cattle were less susceptible to ticks than the Brahman and Simmental. The mechanisms involved in tick tolerance are, as yet, not clearly understood although there is clear evidence of adaptation (Spickett *et al*., 1989). Tick avoidance behaviour, skin sensitivity and increased grooming activity by Zebu, Sanga and *Bos indicus* breeds may account for the lower numbers of ticks when compared to tick numbers on exotic *Bos taurus* breeds (Meltzer, 1996). Since ticks may affect cattle productivity, studies to determine the extent to which tick load affects growth, carcass characteristics and meat quality per given breed are warranted.

2.3. Productive performance of cattle under natural grazing

Liveweight, average daily gain (ADG) and carcass characteristics are important parameters in beef production. The productive performance of cattle in communal areas is generally low because of lack of limited livestock and grazing management procedures (Bester *et al*., 2001). The animals' performance is lower than expected. The respective average standardized male growth test final liveweights (Phase C, which is an evaluation of young bulls at central testing centres under standardised intensive conditions) for the Nguni, the Bonsmara and Angus are 321, 437 and 467 kg (Bergh, 1999; Bergh & Gerhard, 1999), but these targets are not achieved in communal areas. While liveweight is largely a result of size at maturity, biological type and growth rate (Hoving-Bolink, Hanekamp, Wastra, 1999; Short, Grings, MacNeil, Heithschimdt, Williams, & Bennett, 1999; Alberti *et al*., 2005) it depends much on the quantity and quality of pasture available. The indigenous Nguni of South Africa are small to medium sized and are

adapted to harsh environments (Collins-Luswet, 2000). The Nguni breed is resilient to tick-borne diseases, has high reproductive levels and has low maintenance requirements (Schoeman, 1989; Strydom *et al.*, 2001). The Bonsmara breed, which is a composite South African breed, contains 3/16 Hereford, 3/16 Shorthorn, and 5/8 Afrikaner (Porter, 1991), is considered a Sanga breed (Felius, 1995). It is also a hardy, heat resistant beef producer (Porter, 1991).

Utilization of appropriate biological types of cattle with proper dietary regimes could allow for superior end-product (Koch, Dikeman, & Crouse, 1982), either in carcass weight or quality. Indigenous cattle breeds, such as the Nguni have lighter carcass weights than exotic breeds, such as the Angus. Dual-purpose breeds have been reported to have lower dressing percentage than pure beef breeds because coefficients of growth for non-carcass fat are higher than those for carcass fat (Kempster, Chawick, & Charles, 1982; Keane, More O'Ferrall, Conolly, & Allen, 1990; King *et al.*, 2006). Purchas, Banton and Hunt (1992) found that carcasses from large framed and late maturing breeds have less fat, higher conformation scores, dressing percentage and proportion of first category cuts.

2.4. Meat quality

Meat quality is the compositional quality (lean to fat ratio) and the palatability. The major parameters considered in the assessment of meat quality are appearance, juiciness, tenderness, and flavour (Lawrie, 1998). Meat should have a desirable colour that is uniform throughout the entire cut. The colour is related to the level of the protein

pigment, myoglobin, present in the muscle. Meat should also have marbling (intramuscular fat) throughout the cut. Marbling increases juiciness, tenderness, and flavour of the meat. Water holding capacity is a factor that also determines the juiciness of meat. It is defined as the ability of meat to retain its water during application of external forces such as cutting, heating, grinding, or pressing (Lawrie, 1998). If excess water is observed at the bottom of the retail package, it may lead to a dry cooked product.

In each stage from growth to slaughter there are factors such as stress, aging, pH, breed, and others that may affect the quality of meat. The transformation of slaughter animals into meat is a chain of events including handling and loading on the farm, transport to the market, pens or slaughterhouse, off-loading and holding and finally slaughter. During these procedures poor operational techniques and facilities will lead to unnecessary suffering, injury and poor quality meat production.Breed type and slaughter weight influence carcass and meat quality parameters in several ways, including the properties and structure of muscle and meat physiology (Sañudo, Macie, Olleta, Villarroel, Panea & Alberti, 2004).

Although it is established that breed and feeding management influence the quality of meat (Wheeler, Cundiff, Koch & Crouse, 1996; Sañudo *et al*., 2004; Andersen *et al*., 2005), there are conflicting reports on the effect of feeding management on meat quality (Priolo, Micol, & Agabriel, 2001). No information is available on the meat quality of Nguni cattle raised on natural pasture without dietary supplementation, as is practiced in communal areas. Meat is composed of physical and chemical components. The physical and chemical meat quality parameters described in this chapter are summarised in Table 2.1. Most of the meat quality parameters can be affected by the way the animals

Table 2.1

Ranges of values of some beef quality characteristics as reported in literature

Meat quality characteristic	Range of values	Source
Lightness (L*)	33.2 – 41	Muir *et al*. (2000), Strydom *et al*. (2005), Zhang *et al*. (2005), Razminowicz *et al*. (2006)
Redness (a*)	11.1 – 23.6	Muir *et al*. (2000), Byrne *et al*. (2000), Strydom *et al*. (2005), Zhang *et al*. (2005), Razminowicz *et al*. (2006)
Yellowness (b*)	6.1 – 11.3	Muir *et al*. (2000), Strydom *et al*. (2005), Zhang *et al*. (2005), Razminowicz *et al*. (2006)
Colour saturation	16.1 - 20.9	Strydom *et al*. (2005), Zhang *et al*. (2005)
Sarcomere length (µm)	1.75 – 2.31	Strydom *et al*. (2000), Maher *et al*. (2005), Strydom *et al*. (2005), Stolowski *et al*. (2006)
WBSF2 (Kg)	38.1 – 143.6	Byrne *et al*. (2000), Campo *et al*. (2000), Muir *et al*. (2000), Maher *et al*. (2005),
WBSF21 (Kg)	16.9 – 59.9	Campo *et al*. (2000), Muir *et al*. (2000), Sañudo *et al*. (2004)
MFL2 (µm)	34.2	Strydom *et al*. (2005)
MFL14 (µm)	24.7	Strydom *et al*. (2005)
pH	5.50 - 6.70	Lahucky *et al*. (1998), Maher *et al*. (2005), Razminowicz *et al*. (2006)
Drip loss (%)	0.14 - 3.89	Byrne *et al*. (2000), Strydom *et al*. (2005), Revilla & Vivar-Quintana (2006)
Water holding capacity (%)	37.0 - 72.7	Strydom *et al*. (2005), Zhang *et al*. (2005), Revilla & Vivar-Quintana (2006)
Cook loss (%)	13.1 -34.54	Byrne *et al*. (2000), Vestergaard *et al*. (2000), Strydom *et al*. (2005), Razminowicz *et al*. (2006)
Moisture (%)	73.87 - 74.08	Maher *et al*. (2005),
Protein content (%)	22.70 - 22.87	Maher *et al*. (2005),
Fat content (%)	0.81 – 3.0	Vestergaard *et al*. (2000), Maher *et al*. (2005), Aldai *et al*. (2006), Alfaia *et al*. (2007)

respond to stress associated with loading, transporting, offloading and pre-slaughter environment novelty.

2.4.1. Stress responsiveness and meat quality

The two main stress-responsive neuroendocrine systems that play a critical role in the regulation of energy fluxes are the hypothalamic–pituitary–adrenocortical (HPA) and the sympathetic nervous system (SNS) (Foury, Devillers, Sanchez, Griffon, Le Roy & Morme`de, 2005). The HPA axis influences feeding behavior, pancreatic hormone secretion, energy expenditure and the protein/lipid balance while the catecholamines (epinephrine and norepinephrine) released by the SNS increase the use of energy stores (glycogen and lipids; Scheurink & Steffens, 1990) and exert anabolic effects on protein metabolism (Navegantes, Migliorini, & Kettelhut, 2002). It is also possible that the adrenal cortex and medulla are somehow co-activated, but that the HPA axis and the SNS are largely independent (Foury *et al*., 2005).

Animals waiting for slaughter can be stressed by either psychological factors such as restraint, handling, or the novelty of the pre-slaughter environment; or physical factors such as hunger, thirst, fatigue, injury, or thermal extremes. Animals' stress responsiveness can be assessed using the concentrations of catecholamines and dopamine in urine (Young, Rosa, & Landsberg, 1984; Hay & Mormede, 1998; Parker, Hamlin, Coleman, & Fitzpatrick, 2004). Catecholamines are often implied as the cause of the

depletion of glycogen in the pre-slaughter period (O'Neill, Webb, Frylinck & Strydom, 2006).

If any animal is stressed in an environment, such as the immediate pre-slaughter period, there is a rapid release of catecholamines which rapidly mobilise and deplete glycogen (Lacourt & Tarrant, 1985). Epinephrine activates muscle adenylate cyclase and thereby stimulates glycogen breakdown (Voet & Voet, 1995). The concentrations of these hormones are the result of neuronal washout from tissues with sympathetic nerves and are therefore important indicators of sympathetic nervous system activity (Young *et al*., 1984). The depleted levels of glycogen result in high ultimate pH (pHu) levels that are not good for the conversion of muscle into meat. According to Tarrant (1989), when pre-slaughter muscle glycogen reserves fall below the critical threshold of 45-55 mmol/kg, the normal pHu in meat (5.5 – 5.6) will not be attained. The measurement of the stress hormones in urine is non-invasive and their levels in urine are not affected by the massive release of catecholamines and dopamine associated with slaughter because there is a delay between elevation of their concentration in plasma and subsequent elevation in the urine (Lay, Friend, Bowers, Grissom, & Jenkins, 1992; Hay, Meunier-Salau, Brulaud, Monnier, & Morme`de, 2000).

Most of the reports on stress responsiveness and meat quality tend to either separately focused on animal welfare (Sowers, Beck, Stern, & Asp, 1983; Lay *et al*., 1992; Ahmadzadeh, Barnes, Gwazdauskas, & Akers, 2006), endocrinology (Hay & Mormede, 1998; Koch, 2004; Parker *et al*., 2004) and meat quality (Silva, Patarata, & Martins, 1999; Zhang, Farouk, Young, Wieliczko, & Podmore, 2005; Mounier,

Dubroeucq, Andanson, & Veissier, 2006), on single quality traits such as pH (Mach, Bach, Velarde & Devant, 2007), or speculate on the relationship between the three (Gardner, McIntyre, Tudor, & Pethick, 2001; O'Neill *et al*., 2006; Mota-Rojas *et al*., 2006) without quantifying the relationships among them. While Foury *et al*. (2005) quantified relationships between stress responsiveness and hormones in pigs no report has sought to establish the strength of the relationship of stress responsiveness and meat quality within these cattle breeds under natural pasture grazing. There is, therefore, need to evaluate the relationship between stress responsiveness and meat quality of Nguni, Bonsmara and Angus cattle raised under conditions that mimic rural conditions and management systems, where animals do not get dietary supplementation.

2.4.2. Physical meat attributes

2.4.2.1. pH and meat quality

Meat tenderness is related to pHu value and meat colour (Byrne, Troy, & Buckley, 2000; Strydom *et al*., 2000; Vestergaard, Therkildsen, Henckel, Jensen, Andersen, & Sejrsen, 2000). Stress prior to slaughter is one of the most important influences on pHu and ultimate meat tenderness. It may be from transportation, rough handling, inclement temperatures, or anything that causes the animal to draw on its glycogen reserves before slaughter.

Grass-fed animals have darker meat than the ones which grain-fed (Muir, Beaker, & Brown, 1998). This is caused by the higher pHu values found in beef from grass-fed

compared to grain-fed cattle. Muir *et al*. (1998) hypothesised that grass-fed steers are more susceptible to pre-slaughter stress and associated pre-slaughter glycogen depletion than grain-fed steers as the latter would be better accustomed to penning and handling. However, French, O'Riordan, Monahan, CaVrey, Vidal and Mooney (2000) and Razminowicz, Kreuzer and Scheeder (2006) reported no such difference in ultimate pH between grass-fed and grain-fed steers.

2.4.2.2. Colour and meat quality

Meat colour is the most important factor affecting consumer acceptance, purchasing decisions and satisfaction of meat products. Colour measurements are done using the Commission International De I' Eclairage (CIE) colour system (Commission International De I' Eclairage, 1976). The three fundamental colour coordinates are L*, a* and b*. The L* measures the lightness and is a measure of the light reflected (100 = white; 0 = black); a* measures positive red, negative green and b* measures positive yellow, negative blue (Commission International De I' Eclairage, 1976).

Meat colour may be influenced by many factors such as enzymes, diet, and age of the animal and even the activity done by the animal. For example, myoglobin, a protein, responsible for the majority of the red colour in meat does not circulate in the blood but is fixed in the tissue cells and is purplish in colour. When it is mixed with oxygen, it becomes oxymyoglobin, and produces a bright red colour which is measured objectively by a* coordinates (Priolo *et al*., 2001). The remaining colour comes from the haemoglobin which occurs mainly in the circulating blood, but a small amount can be

found in the tissues after slaughter (Priolo *et al*., 2001). When the muscle glycogen has been used up rapidly during the handling, transport and pre-slaughter period, the results after slaughter is little lactic acid production which result in DFD meat, and this condition is measured by an L* coordinates (Commission International De I' Eclairage, 1976). This DFD meat is of inferior quality as the less pronounced taste and the dark colour is less acceptable to the consumer and has a shorter shelf life due to the abnormally high pH value which is conducive to bacterial growth (Priolo *et al*., 2001). Zhang *et al*. (2005) found that high pH meat had lower L* (lightness), a* (redness), b* (yellowness), hue angle (degrees) and chroma (saturation) values than normal pH meat, indicating that high pH meat was darker and less brown than normal pH meat.

Animals fed on pasture have a yellow fat colour because of the high levels of beta-carotene contained by grass. This yellow fat colour is measured objectively by b* coordinates. Consumers often perceive meat with yellow fat as having come from an old or diseased animal. In addition, forage-based rations, as well as different forage and seasonal changes, allow for carcasses with a darker lean appearance or fat that is yellow in appearance (Baublits, *et al*., 2004). The darker lean (low *L** values) may be attributed to increased myoglobin, decreased muscle glycogen, or both, and the yellow fat (Priolo *et al*., 2001). Grass-fed cattle could be more stressed than grain-fed cattle due to differences in human exposure (Andersen *et al*., 2005) or that grazing animals exhibit more myoglobin than confined animals due to differences in physical activity (Shorthose & Harris, 1991), hence differences in meat colour. There are also differences in antemortem glycogen and its effect on pH of meat, or differences in marbling and its effects on lean colour (Baublits *et al*., 2004). Vestergaard, Oksbjerg and Henckel (2000) reported less

glycogen, a higher pH, and darker lean from younger bulls that were fed a forage-limited diet than those fed a concentrate *ad libitum*. These authors speculated that the decreased dietary energy on the forage-limited diet favoured an increase in oxidative muscle metabolism. An increase in oxidative muscle metabolism could possibly allow for the decreased necessity to store comparable amounts of muscle glycogen as muscle with a higher glycolytic capacity. The resultant pH differences caused differences in yellowness (b*). Vestergaard *et al*. (2000) reported a negative correlation between pH and *b** values.

Although there are contrasting reports on breed effects on meat colour, differences in meat colour have been associated with variations in intramuscular fat and moisture content, age dependent changes in muscle myoglobin content (Lawrie, 1998) and the pHu of the muscle (Hector, Brew-Graves, Hassen, & Ledward, 1992), with higher pHu being associated with dark cuts. Some authors (Muir, Wallace, Dobbie, & Brown, 2000; Chambaz, Scheeder, Kreuzer, & Dufey, 2003; Revilla & Vivar-Quintana, 2006) reported no breed effects on colour. According to O'Neill *et al.* (2006), Nguni steers produced darker meat than the improved breeds. Although the causes of the differences in meat colour were not fully understood O'Neill *et al.* (2006) observed that Nguni cattle released more catecholamines than exotic breeds, during the pre-slaughter period, causing the depletion of glycogen.

2.4.2.3. Water holding capacity and drip loss

Water holding capacity (WHC) is defined as the ability of meat to retain its water during application of external forces such as cutting, heating, grinding, or pressing (Zhang *et al*., 2005). Water holding capacity of meat is greatly affected by pH. It is important to meat processing in that as proteins are able to hold more water they become more soluble. In meat WHC is at a minimum at the iso-electric point (pI) of proteins (Zhang *et al*., 2005). At this point, equal positive and negative charges on the amino acids side chains result in a maximum number of salt bridges between peptide chains and a net charge of zero. The pI of meat is in the pH range of 5.0 to 5.5 which is also the pH of meat after it has gone through rigor mortis (Zhang *et al*., 2005). The exposure of proteins to a low pH at high temperatures causes less water to be retained between actin and myosin filaments, thus increasing exudates (drip loss). Actin and myosin are important in the formation of a protein lattice necessary for binding water and fat in further processed meat products (Zhang *et al*., 2005).

In contrast, increasing or decreasing the pH away from the pI will result in increased water-holding capacity by creating a charge imbalance (Zhang *et al*., 2005). A charge imbalance is a predominance of either positive or negative charges which will lead to a repulsion of charged protein groups of the same charge. This repulsion results in increased capacity for water retention and lead to a juicy meat. Zhang *et al*. (2005) reported higher water holding capacity in high pH meat than in normal pH meat.

Aldai *et al*. (2006) and Uytterhaegen, Claeys, Demeyer, Lippens, Fiems and Boucque (1994) reported breed effects on drip loss with double-muscled animals

showing increased drip loss in beef. Oliva´n, Martı´nez, Osoro, San˜udo, Panea and Olleta (2004) also found that raw meat of double-muscled animals had higher drip loss and hence lower water-holding capacity than meat from heterozygous bulls. This effect could be the result of several factors including, higher glycolytic metabolism in muscle of double-muscled animals (Gagnie`re, Picard, Jurie, & Geay, 1997; Oliva´n *et al*., 2004), differences in collagen structure (Uytterhaegen *et al*., 1994), or the lower IMF content of double-muscled meat (Oliva´n *et al*., 2004). Aldai *et al*. (2006) found that when IMF content was high there was a concomitant lower result for juice loss from raw meat, measured as the expressible juice under pressure. A rapid pH fall or a lower pH would tend to cause protein denaturation and greater drip loss.

2.4.2.4 Meat tenderness

Tenderness can be attributed to a person's perception of meat, such as: softness to tongue, resistance to tooth pressure and adhesion. Sources of tenderness variation in beef for instance may be attributed to animal's age, sex, liveweight, breed and antemortem stress. Tenderness varies mainly due to changes to the myofibrillar protein structure of muscle in the period between animal slaughter and meat consumption (Muir *et al*., 2000). For example, if the carcass is refrigerated too hastily immediately after slaughter, muscle fibres contract severely, and the result is 'cold shortening' which will need a force to shear the fibres after cooking (Razminowicz *et al*., 2006). Thus, the tougher the meat, the more force required to shear it and that is known as the Warner-Bratzler shear force (WBSF) test.

Muir *et al*., (2000) and Monson, Sañudo and Sierra (2005) argued that meat tenderness is a function of the collagen content, heat stability and the myofibrillar structure of muscle. These, however, appear to be affected mainly by the rate of growth of the animal rather than breed *per se*. The myofibrillar component of tenderness can also be influenced by the calpain proteolytic enzyme system during ageing of the carcass post-mortem. Wheeler and Koohmaraie (1991) suggested that the myofibrillar component could be a more important factor than the connective tissue characteristics in influencing meat tenderness. Pasture beef turned out to have WBSF than conventional beef (Razminowicz *et al*., 2006). However, French *et al*. (2000) found no difference in WBSF between beef produced on grass-based and concentrate-based diets.

While the biochemical changes that occur in beef muscle postmortem are largely understood, the relationship between these changes and variation in meat tenderness remains unclear and requires quantification (Koohmaraie, 1996). Koohmaraie, Kent, Shackelford, Veiseth and Wheeler (2002) suggested sarcomere length, connective tissue and proteolysis of myofibrillar proteins could explain most of the variation observed in aged meat, with proteolysis being the main biochemical factor contributing to the variation in tenderness. Maher, Mullen, Buckley, Kerry and Moloney (2005) found that variation in proteolysis was greater than the other biochemical, chemical and tenderness quality attributes in Belgian Blue steers managed homogenously pre and post-slaughter. Furthermore, Koohmaraie *et al*. (2002) hypothesised that protein degradation occurs at different rates in different animals, which may contribute to the variation in tenderness of beef.

Different breeds of cattle have a wide spectrum of fibre types in muscles (Campo *et al*., 2000; Gil *et al*., 2001) but these are not always reflected by differences in instrumental analyses using Warner Bratzler or sensory panels. However, several authors reported no differences in WBSF values due to breed when animals are slaughtered at the same age (Muir *et al*., 2000; Revilla & Vivar-Quintana, 2006). Strydom *et al*. (2001) also reported no differences in WBSF values among Nguni and Bonsmara steers that were raised in a feedlot. Stolowski *et al*. (2004) reported significant breed and breed by ageing interaction effects on meat tenderness with those animals with higher levels of Angus blood being tender than those that had lower Angus blood. Sañudo *et al.* (2004) found that differences between breed types for most WBSF values were more pronounced at the lower carcass weight than at higher carcass weights. It has also been reported that different breeds had a wide spectrum of fibre types in muscles, but these were not always reflected by differences in instrumental analyses using WBSF or sensory panels (Sañudo *et al*., 2004). Seideman, Crouse and Cross (1986) reported significant breed effects on total and insoluble collagen, which could be more important than weight or even production system in determining meat tenderness. Sañudo *et al.* (2004) reported significant differences in WBSF values among breeds at short ageing times, but the differences disappeared at 21 days, implying that longer ageing times tend to homogenise the product, especially in the heavier animals. A higher slaughter weight and longer ageing time could make the product more homogeneous, independently of the breed type (Sañudo *et al.*, 2004).

Indigenous breeds, such as the Nguni and Zebu, are perceived to have poorer carcass characteristics and to have tougher meat which is more variable in tenderness,

compared to beef from exotic breeds such as the Angus and Hereford. This is because indigenous breeds have greater amounts of calpastatin that reduces post-mortem degradation of muscle by calpains resulting in tough meat (Koohmarie, 1996; Gil *et al*., 2001. Another factor may be that these breeds walk long distances in search of grazing and water; and therefore by that long walking activity their muscles get tough hence there will be more force needed to break their muscle (Scholtz, 2005). Most indigenous breeds grow naturally without any growth supplements such that by the time they reach a required slaughter weight they are already mature and give a less tender meat. The opposite can be true about the exotic breeds, because of growth supplements they get from the farm; they reach a required slaughter weight rapidly at a younger age and so yield a more tender meat.

Meat tenderness improves with ageing of the muscle. Ageing can be used to decrease shear force values during post-mortem storage as a result of the proteolysis of myofibrillar proteins, which is mediated in part by calpains (Koohmarie, 1996). This tenderization through ageing involves several aspects that affect myofibrillar fragmentation, including animal characteristics, pH and pre-rigor conditioning (Sañudo *et al.,* 2004). The same authors reported a higher rate of tenderization in heavier animals (92 % within the first week) than in lighter animals (67 % within the first week). Stolowski *et al*. (2004) found that aging can improve WBSF values up to 14 days; and, postmortem aging beyond 14 d may not be effective in improving WBSF of steaks from cattle with a large *Bos indicus* influence. Muir *et al*. (2000) reported no differences in WBSF shear force measurements in meat tenderness between breeds when compared at the same age, with ageing complete by six days after slaughter.

2.4.3. Muscle histological and biochemical attributes

2.4.3.1. Sarcomere length

Sarcomere length is used to determine the effectiveness of electrical stimulation as a way of preventing cold shortening. Electrical stimulation reduces the pH of the muscle rapidly and hastens the onset of rigor mortis. Electrical stimulation was primarily developed to accelerate post-mortem glycolysis so that muscles are prevented from excessive shortening when they enter rigor. Stolowski *et al*. (2004) found that electrically stimulated muscles had longer sarcomeres than their non-electrically stimulated counterparts. Cold-shortening occurs most often in carcasses when muscle temperature drops below 10 °C within 8 to 12 hours post-mortem while the muscle pH remains above 6.1. The lowering of the pH of muscle is a result of the conversion of muscle glucose to lactic acid. Cold shortens sarcomere length and meat becomes tough, although this may not happen in some cases (Stolowski *et al*., 2004). Whipple, Koohmaraie, Dikeman, Crouse, Hunt and Klemm (1990) and Stolowski *et al*. (2004) reported that sarcomere length was not affected by breed type.

2.4.3.2. Myofibrillar fragmentation length, aging, tenderness

Ageing is the holding of certain kinds of meat, principally beef, after slaughter, under refrigeration at temperatures ranging from 0˚C to 4˚C, to enhance tenderness and develop flavour. During ageing, an enzyme collagenase produced by bacteria within the

meat breaks down the myofibrillar protein structure and connective tissue protein (Zhang *et al*., 2005). Since myofibrils make up nearly 80% of the volume of the muscle cell, their disruption greatly influence meat tenderness (Zhang *et al*., 2005*)*. Other changes that are correlated with increased tenderness include breakages within the myofibrils themselves, particularly within the I-band. These breakages lead to increased fragility and fragmentation of the myofibrils. The increase in myofibrillar fragmentation is indicative of the amount of tenderization that has taken place in meat (Sañudo *et al*., 2004*)*.

2.4.4. Fatty acid profiles

Beef fat is a significant source of saturated fatty acids in the human diet because red meat has a relatively high ratio of saturated to unsaturated fatty acids in its lipids. This is a risk factor for the development of vascular and coronary diseases (Mills, Comerford, Hollender, Harpster, House, & Henning, 1992; Barton, Marounek, Kudrna, Bures, & Zahradkova, 2007). The adverse effect of saturated fatty acids on the human plasma cholesterol levels makes it imperative to evaluate fatty acid profiles in beef meat.

Breed of cattle and the way cattle are managed may affect fatty acid composition since fatty acid composition is closely related to the fatness level (Zembayashi, Nishimura, Lunt, & Smith, 1995; Barton *et al*., 2007). Fatty acid composition of edible tissues of cattle is influenced by diet and genotype (Barton *et al*., 2007). Padre *et al*. (2006) reported breed differences in lipid content in tissue of cattle, which was indirectly related to conjugated linoleic acid (CLA) content. Some breeds that have a tendency to deposit higher amounts of fat on muscle produce a higher quantity of CLA. However,

Baublits *et al*. (2006) reported no differences between biological types for fatty acid profiles. Breed differences reflect underlying differences in gene expression or activities of enzymes involved in fatty acid synthesis, desaturation or chain elongation, and thus deserve further attention (Choi, Enser, Wood, & Scollan, 2000; Barton, *et al*., 2007). Differences in fatty acid composition between breeds can often be explained by differences in the proportion of intramuscular fat as the ratio of polyunsaturated fatty acid to saturated fatty acid (PUFA/SFA). This ratio decreases with the increasing fat level of beef (Barton, *et al*., 2007) that depends on bree and nutrition. It is therefore imperative to assess the fatty acid profiles of meat from cattle raised on pasture.

Forage-fed beef contains higher proportions of CLA (Padre *et al*., 2006), which exhibits anticarcinogenic properties, and can increase animal body protein (Baublits *et al*., 2006). Furthermore, forage-fed beef can exhibit an improved *n*-6 to *n*-3 fatty acid ratio that has a positive cardiovascular impact (Baublits *et al*., 2006; Razminowicz, *et al*. 2006). Realini, Duckett, Brito, Dalla-Rizza and Mattos (2004) pointed out that pasture-fed animals have a higher concentration of PUFA, stearic (18:0), linoleic (LA), linolenic (LNA), arachidonic (20:4 n-6, AA), eicosapentaenoic (20:5 n-3, EPA), and docosapentaenoic (22:5 n-3, DPA) acids than animals fed on protein concentrates. Fatty acids affect human health in several ways. Table 2.2 summarises fatty acid levels reported by several authors.

Table 2.2

Fatty acid profile (as percentage of the total fatty acids identified) of the *Longissimus thoracis et lumborum* muscle as reported in literature

Fatty acid	Range of values	Sources
C14:0	1.54 – 4.64	Aldai *et al*. (2006), Alfaia *et al*. (2007)
C14:1c9	0.18 - 0.45	Aldai *et al*. (2006),
C15:0	0.30 - 0.67	Aldai *et al*. (2006), Alfaia *et al*. (2007)
C16:0	23.3 - 30.85	Enser *et al*. (1996), Aldai *et al*. (2006), Wood *et al*. (2003), Alfaia *et al*. (2007)
C16:1c9	1.51 – 3.76	Aldai *et al*. (2006), Alfaia *et al*. (2007)
C17:0	0.85 - 1.12	Aldai *et al*. (2006)
C17:1c10	0.39 - 0.65	Aldai *et al*. (2006)
C18:0	13.4 – 16.7	Enser *et al*. (1996), Aldai *et al*. (2006), Wood *et al*. (2003), Alfaia *et al*. (2007)
C18:1t9	5.74 - 5.66	Aldai *et al*. (2006)
C18:1c9	14.56 – 35.2	Aldai *et al*. (2006), Alfaia *et al*. (2007)
C18:2c9,12 (n-6)	9.86 - 23.70	Aldai *et al*. (2006)
C18:2c9t11 (n-6)	0.30 - 0.37	Alfaia *et al*. (2007)
C20:0	8.15 - 9.68	Aldai *et al*. (2006)
C18:3c9,12,15 (n-3)	0.14 - 0.38	Aldai *et al*. (2006)
C22:0	1.05 - 1.85	Aldai *et al*. (2006)
C20:3c11,14,17 (n-3)	0.40 - 1.16	Aldai *et al*. (2006)
C22:2c13,16 (n-6)	0.24 - 0.49	Aldai *et al*. (2006)
PUFA[1]	13.58 - 32.16	Aldai *et al*. (2006)
MUFA[2]	26.39 - 35.71	Aldai *et al*. (2006)
SFA[3]	40.79 - 49.76	Aldai *et al*. (2006)
n-6[4]	5.23 - 29.45	Aldai *et al*. (2006), Alfaia *et al*. (2007)
n-3[5]	1.18 – 4.17	Aldai *et al*. (2006), Alfaia *et al*. (2007)
PUFA:SFA[6]	0.11 - 0.81	Enser *et al*. (1996), Aldai *et al*. (2006), Alfaia *et al*. (2007)
n-6:n-3[7]	1.32 -11.79	Enser *et al*. (1996), Enser *et al*. (1998), Aldai *et al*. (2006), Alfaia *et al*. (2007)

2.4.4.1. Fatty acids and health

Meat healthiness is largely related to its fat content and its fatty acid composition (Fisher, Enser, Richardson, Wood, Nute, & Kurt, 2000). Lipids of green forage contain high proportions of α-linolenic acid (ALA). This basic *n*-3 (omega-3) fatty acid can be endogenously desaturated and elongated to long-chain *n*-3 fatty acids (*n*-3 LC-PUFA) (Razminowicz *et al.*, 2006), i.e. eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA), and docosahexaenoic acid (DHA). Omega-3 fatty acids, particularly the *n*-3 LC-PUFA, were shown to exert various beneficial health effects (Simopoulos, Leaf, & Salem, 1999).

Increasing *n*-3 contents in beef can be relevant to improving human supply with *n*-3 LC-PUFA (Razminowicz *et al.*, 2006). Raes, Balcean, Dirink, De Winne, Claeys and Demeyer (2003) reported that *n*-6/*n*-3 ratios were higher (5–7) for animals fattened under highly intensive production conditions, compared with values of 2.5–3 for animals from extensive production systems. The recommended maximum n-6/n-3 is 5:1 (Razminowicz *et al.*, 2006). Increasing the *n*-3 fatty acid content of animal feed can therefore be a promising and sustainable way to improve the dietetic value of beef without forcing consumers to change their eating habits.

Conjugated linoleic acids (CLA) are another group of fatty acids, which naturally occur in ruminant-derived food and to which various beneficial health effects are ascribed (Belury, 2002). However, scientific evidence for beneficial health effects in humans is variable and still unconvincing (Kramer, Fellner, Dugan, Sauer, Mossoba, & Yurawecz, 1997). There is clear evidence for an enhanced proportion of *n*-3 fatty acids and CLA in

beef from grass-fed bulls compared with beef from bulls fed maize silage and concentrate (Nürnberg, Nürnberg, Ender, Lorenz, Winkler, & Rickert, 2002; Dannenberger, Nürnberg, Scollan, Schabbel, Steinhart, & Ender, 2004). Among the various CLA isomers, *cis*-9, *trans*-11 18:2 (18:2*c*9*t*11) is the predominant isomer naturally occurring in ruminant products and is particularly believed to be beneficial for human health (Kramer *et al*., 1997; Vatansever *et al*., 2000; Razminowicz *et al*., 2006). The 18:2*c*9*t*11 is mainly a product of endogenous desaturation of *trans*-vaccenic acid (18:1*t*11), which is the predominant 18:1-*trans* isomer in grass-fed cattle (Dannenberger *et al*., 2004). Accordingly, Chin, Liu, Storkson, Ha and Pariza (1992) claimed that the best dietary sources of CLA are foods produced by grass-fed ruminants.

In addition to possible health effects (Aharoni, Nachtomi, Holstein, Brosh, Holzer, & Nitsan, 1995; Padre *et al*., 2006; Barton, *et al*., 2007), fatty acid profiles may affect the sensory characteristics of meat (Wood *et al*., 2003). Assessment of fatty acid profiles of cattle breeds in particular production systems is therefore needed.

2.4.5. Sensory evaluation of meat

In order to determine the acceptance of a food product, consumers consider several characteristics, such as its sensory characteristics, nutritional value, convenience and impact on health (Wood *et al*., 2003). The sensory, health related and nutritional properties are the most important motivators for liking and purchasing of meat (Verbeke & Viaene, 1999). The most important quality aspects of beef are tenderness, juiciness, the way that it tastes and that it is fresh, lean, healthy and nutritious (Grunert, 1997). Muier *et*

al. (2000) reported that despite the yellower fat of the Friesian steers, there was no difference in eating quality of the meat produced by Hereford and Friesian steers, suggesting that fat colour has no measurable relationship with meat eating quality.

Sensory values for tenderness tend to be higher as the ageing time (Campo, Panea, Albertí, & Santolaria, 1999; Monsón *et al*., 2005). In a study by Monsón *et al*. (2005) aging time did not affect juiciness in the Spanish Holstein and the Blonde d'Aquitaine while it affected juiciness in the Limousin and the Brown Swiss, the values found at 3 and 7 days being the highest in both breeds. Juiciness values decreased from 14 days of ageing (Monsón *et al*., 2005). This could be partly explained by the weakening of muscle structure, which may produce higher losses of liquid during cooking.

Dransfield, Nute, Roberts, Boccard, Touraille and Buchter (1984) postulated that tenderness and juiciness were the properties that most influence meat acceptability. Monsón *et al*. (2005) reported that partial correlations between sensory variables indicated that tenderness (r = 0.60), juiciness (r = 0.59) and beef flavour intensity (r = 0.49) were the attributes that most influenced the acceptability of meat. The same authors found that the highest correlation coefficient was observed for beef flavour (0.22) and the lowest for bitter flavour (-0.10). Table 2.3 summarises sensory scores reported by several authors.

Table 2.3

Ranges of sensory scores of some meat quality characteristics aged for 2 and 21 days as reported in literature

Meat sensory characteristic	Range of values	Source
Taste at 2 days	4.7 – 5.5	Strydom *et al*. (2005), Revilla & Vivar-Quintana (2006)
Taste at 14 days	5.8	Strydom *et al*. (2005)
Aroma at 2 days	5.21 - 5.61	Monsón *et al*. (2005)
Aroma at 21 days	5.02 – 5.39	Monsón *et al*. (2005)
Juiciness at 2 days	3.3 - 6.6	Byrne *et al*. (2000),
Juiciness at 21 days	4.38 – 4.86	Monsón *et al*. (2005)
Flavour at 2 days	3.1 – 5.89	Byrne *et al*. (2000), Monsón *et al*. (2005)
Flavour at 21 days	5.39 - 5.93	Monsón *et al*. (2005)
Tenderness at 2 days	2.1 - 6.4	Byrne *et al*. (2000), Maher *et al*. (2005), Monsón *et al*. (2005)
Tenderness at 21 days	5.98 – 6.47	Monsón *et al*. (2005)
Residual at 2 days	4.19 - 4.98	Monsón *et al*. (2005)
Residual at 21 days	4.21 – 4.76	Monsón *et al*. (2005)
Overall acceptability at 2 days	1.8 – 5.65	Byrne *et al*. (2000), Monsón *et al*. (2005)
Overall acceptability at 21 days	4.26 -4.94	Monsón *et al*. (2005)

2.4.6. Correlations among meat quality traits

Modern meat production techniques aim to increase muscle weight and meat quality, but these characteristics are not always positively correlated (Sañudo *et al*., 2004). There are various reports on relationships among meat quality traits. For example meat tenderness is related to ultimate pH (pHu) value and meat colour (Byrne *et al*., 2000; Strydom *et al*., 2000; Vestergaard *et al*., 2000). There are also some relationships between meat quality traits, fatty acid profiles and sensory characteristics of meat (Jeremiah, Alhus, Robertson, & Gibson, 1996; Wood *et al*., 2003).

Strydom *et al*. (2000) and Revilla and Vivar-Quintana (2006) reported negative correlations between sarcomere lengths and WBSF values. This can be ascribed to the fact that muscles with short sarcomere length are generally tough. Usually there are positive correlations between WBSF values and MFL values in most cattle breeds. This can be attributed to the fact that meat tenderness is a function of the collagen content and the myofibrillar structure of muscle (Muir *et al*., 2000; Revilla & Vivar-Quintana, 2006). Furthermore, the variation in WBSF values depend more on the myofibrillar content than the total collagen content or its solubility, especially considering that shear force on cooked meat may also be a measure of myofibrillar toughness (Sañudo *et al*., 2004). Strydom *et al*. (2000) reported significant within-breed correlations between myofibrillar fragmentation index (MFI) and tenderness. Beef crosses with more Angus blood aged faster than those crosses with less Angus blood (Stolowski *et al*., 2006).

There is a relationship between drip loss, IMF and pH. Aldai *et al*. (2006) found that when IMF content was high there was a concomitant lower result for juice loss from raw meat, measured as the expressible juice under pressure. A rapid pH fall or a lower pH would tend to cause protein denaturation and greater drip loss. Some meat quality correlations are reported in Table 2.4.

Table 2.4
Correlations between glycogen level and some technological meat quality values

	glycogen (ante mortem)	glycogen (1 hr ***post mortem)***	glycogen (3 hr ***post mortem)***	glycogen (48 hr ***post mortem);***	pH at 48 hours	cooking loss	Warner-Bratzler shear force.
glycogen (ante mortem)		0.60**	0.70**	-0.04	-0.67**	0.65**	0.44*
pH glycogen (1 hr ***post mortem)***			0.81**	-0.01	-0*73**	0.70**	0.36
glycogen (3 hr ***post mortem)***				0.02	-0.78**	0.75**	0.39*
Protein glycogen (48 hr ***post mortem);***					- 0.04	0.08 -	0.06
pH at 48 hours						-0.79**	-0.58*
cooking loss							- 0.48*

Significantly correlated at * P < 0.05, ** P < 0.01, ***P < 0.001.

Source: Lahucky *et al*. (1998).

2.5. Summary of literature review

From the preceding review it can be seen that there are several factors that interact and affect meat quality and the consumer perception of meat eating quality. The factors range from the way the animals are raised, transportation to the abattoir, post-slaughter handling and the keeping of meat in butcheries, shops and home. Different factors at every stage should be considered to improve meat quality. The broad objective of the current study was, therefore, to assess the growth performance, tick loads, carcass characteristics and the meat quality of the Nguni, Bonsmara and Angus steers reared on natural pasture.

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CHAPTER 3: Tick susceptibility and its effects on growth performance and carcass characteristics of Nguni, Bonsmara and Angus steers raised on natural pasture

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Abstract

The objective of the current study was to compare tick loads, growth and carcass characteristics of dipped and non-dipped Nguni, Bonsmara and Angus steers raised on natural pasture. One hundred seven-month old castrated weaners were kept at the University of Fort Hare Farm for 12 months. There were 30 weaners each of Angus and Bonsmara, and 40 weaners of the Nguni breed. Half the Bonsmara, Angus and 14 Nguni weaners were dipped every fortnight. The rest were not dipped. Monthly weights and tick counts under the tail, on scrotum, belly, sternum and ears of the steers were recorded. The dipped Nguni steers had lowest ($P < 0.05$) tick counts, and the non-dipped Angus steers had the highest tick counts. There were more ticks ($P < 0.05$) during the warm wet season than during the cool dry season. Ears had the highest ($P < 0.05$) tick infestation. Average daily gain (ADG) was similar ($P > 0.05$) among the three breeds. The non-dipped Bonsmara steers had the heaviest ($P < 0.05$) carcasses (142 ± 5.4) while the non-dipped Nguni steers were the lightest (111 ± 4.5 kg). The non-dipped Bonsmara had the highest ($P < 0.05$) eye muscle area (3996 ± 120.8 mm^2) while the non-dipped Angus had the smallest eye muscle area (3291 ± 210.6 mm^2). The non-dipped Bonsmara also had the highest ($P < 0.05$) dressing percentage (53.8 ± 1.01) while the non-dipped Nguni had the lowest (50.3 ± 0.84) dressing percentage. The current study has shown that while the non-dipped steers had higher tick loads than the dipped ones, their growth and carcass characteristics were similar. The study has also shown that, despite being a small-framed breed, the Nguni steers had similar ADG to the large-framed Bonsmara and Angus steers. Therefore, the Nguni cattle have got the potential to produce organic beef. However, a reasonable assessment of organic meat production potential of the Nguni requires an evaluation of its meat quality traits under natural pasture.

Keywords: Animal growth, carcass, Nguni cattle, natural pasture, ticks

3.1. Introduction

The Nguni breed is increasingly attracting international interest, mainly due to its resilience to tick-borne diseases, high reproductive performance, good walking and foraging ability, and low maintenance requirements (Muchenje, Dzama, Chimonyo, Raats, & Strydom, 2007, Appendix 1), acquired through centuries of natural selection (Schoeman, 1989; Strydom *et al*., 2000; 2001). It can be reared on natural pasture without use of chemicals or dietary supplementation in the communal areas of South Africa. Communal grazing involves the grazing of cattle from different households on the same piece of land (Bester *et al*., 2001). Although individual households own the cattle, grazing is owned by the community. Normally there is limited livestock and rangeland management principles applied resulting in rangeland deterioration and poor livestock conditions. Although feed quantity and quality is adequate during the rainy season, biomass yield declines during the dry season, resulting in cattle losing bodyweight (Muchenje *et al*., 2007). To counter the need for dietary supplementation, farmers sometimes sell their animals for slaughter before marked weight losses begin. With its desirable characteristics and the cattle production systems in communal areas, where no chemicals or dietary supplementation is used, the Nguni has the potential for organic meat production as prescribed by AFRISCO (2001).

Despite the possible limitations associated with production of natural-based meat, modern consumers are increasingly concerned about the production systems and animal welfare requirements for the growing animals (Andersen *et al*., 2005). This concern has been also accompanied by an increased preference for naturally or organically produced meat. A

considerable amount of work on tick infestation and meat production has been conducted on cultivated pastures and in feedlots (Gertenbach & Henning, 1995; Collins-Luswet, 2000). Very little, if any, work has been done under natural grazing conditions, as is commonly practised in the rural areas. Furthermore, most studies in South Africa on ticks (Spickett *et al*., 1989; Webb & David, 2002; Schwalbach *et al*., 2003), growth and meat production (Muchenje *et al*., 2007) covered these aspects separately yet ticks could affect animal productivity and ultimately meat production.

Although it is a small to medium sized, the indigenous Nguni cattle breed of South Africa is reported to be adapted to harsh environments (Collins-Luswet, 2000). The Bonsmara competes favourably with European beef cattle while withstanding subtropical conditions, such as high temperatures, ticks and most tick-borne illnesses. They are well muscled with high meat yield and quality. However, they are not as well adapted to harsh conditions as the Nguni breed. The Angus is Scottish breed with desirable meat related characteristics, such as early maturity and marbling (Andersen *et al*., 2005). However it tends to be susceptible to ticks and tick – borne diseases.

Ticks limit animal productivity (Mugisha, McLeod, Percy, & Kyewalabye, 2005; Johnsson, 2006; Kivaria, 2006). Farmers commonly use acaricides to control ticks. Indiscriminate use of acaricides may, however, lead to the development of resistance, environmental contamination and limited success in the control of ticks and tick-borne diseases (Frisch, 1999; Kamidi & Kamidi, 2005). The use of acaricides and other chemicals is also discouraged in organic meat production. Furthermore, regular dipping to prevent tick infestation is a costly exercise for the emergent farmer since it results in increased veterinary and labour costs, possible resistance to ticks, animal movement and handling. Alternative approaches include use of adapted indigenous cattle breeds (Meltzer, 1996). In most communal areas of South Africa, cattle are rarely or less frequently dipped. The Nguni Society of South Africa discourages the dipping of the Nguni cattle

because the breed has tick immunity it acquired over the years (Hobbs, 2005). The Nguni, can therefore play a significant role in the production of high value organic beef because it needs little, if any, chemical tick control and dietary supplementation (Muchenje *et al*., 2007). However, no studies have been done on tick tolerance, growth and carcass characteristics of dipped and non-dipped indigenous cattle under communal grazing systems in rural areas. The objective of this study was, therefore, to compare tick loads, growth and carcass characteristics of non-dipped Nguni, dipped Nguni, Bonsmara and Angus steers that were kept on natural pasture without dietary supplementation. It was hypothesized that, when grazing on natural pasture and under similar tick control measures, growth and carcass characteristics of the indigenous dipped and non-dipped Nguni cattle breed is similar to that of Bonsmara and Angus.

3.2. Materials and Methods

3.2.1. Animal management and measurements

Thirty weaners of each of Bonsmara and Angus breed, and 40 weaners of Nguni breed of similar age (around 205 days) were raised at Honeydale Farm, University of Fort Hare till slaughter at 18 months of age. The details of the site where the study was conducted, how the animals were managed and slaughtered were as described by Muchenje *et al*. (2007). Half the Bonsmara, Angus and 14 Nguni steers were dipped in a conventional spray race using a commercial acaricide, Decatix 3® (Cooper Veterinary Products (Pty) Ltd, Registration Number. 2002/021376/07 , Pretoria, Republic of South Africa), every two weeks. Decatix® contained deltamethrin as an active agent. Tick counts were done under the tail, on the belly, the ear, the

scrotum and the sternum before each dipping. Monthly weights of all animals were recorded to compute growth rates of the steers. Average daily gain (ADG) (g/day) between weaning (initial weight) and slaughter (slaughter weight) was calculated**.**

The grade classification used in South Africa considers age (A = 0 teeth, AB = 1-2 teeth, B = 3-6 teeth, and C = more than 6 teeth) and fatness (fatness scale 0 – 5, with 0 = no visual fat cover, 1 = very lean, 2 = lean, 3 = medium, 4 = fat, 5 = overfat, and 6 = excessively overfat) (South African Meat Industry Company, 2006). The South African Meat Industry (2006) uses a conformation scale of 1-5 (with 1 = a very flat carcass, 2 = a flat carcass, 3 = medium carcass, 4 = a round carcass, and 5 = a very round carcass). The dressing out percentage was calculated as warm carcass weight expressed as a percentage of the liveweight. Carcasses were split, weighed and then chilled at between 0 and 3^{o}C for 24 hours. The eye muscle area was measured by tracing the muscle area between the 10th and 11th thoracic vertebrae. The surface area was then determined by video image analysis (VIA, Kontron, Germany).

3.2.2. Statistical analyses

After testing for normality, average daily gain (ADG), carcass characteristics and tick counts were analyzed using GLM procedures of SAS (2000). A repeated measures model with monthly weight as a repeated measure and steer as a random variable was fitted for monthly weights of the steers in SAS (2000). For tick counts, the main factors fitted in the model were breed (Nguni, Bonsmara and Angus), position of tick on the steer (under tail, scrotum, belly, sternum and ear), dipping (whether the steers were dipped or not), month and their interactions. For ADG and carcass characteristics, breed and dipping was considered as the main factor.

Comparison of means was done using the PDIFF procedure (SAS, 2000). A chi-square test (SAS, 2000) was used to test whether any associations existed between breed and carcass classification grade.

3.3. Results and discussion

3.3.1. Effect of breed and dipping on tick counts

The most common tick species in this study were the Blue tick (*Boophilus annulatus*) and the Bont tick (*Ambylomma hebraeum*) with each representing 38 % of the total ticks identified. The other species found were the Red-legged tick (*Rhipicephalus evertsi evertsi*) (19 %) and the Bont-legged tick (*Hyalomma spp*) (5 %). There were isolated cases of the Brown ear tick (*Rhipicephalus appendiculatus*). Tick counts were significantly ($P < 0.05$) influenced by the breed, position of ticks on the steer and month. All the interactions among the main factors were significant ($P < 0.05$). There were more ticks ($P < 0.05$) during the warm wet months (November to March) than during the cool dry months (May to July) (Figure 3.1). The higher tick infestations in the warm wet season than the dry cold season could be ascribed to the more conducive conditions for their breeding. Ticks breed and survive when humidity and ambient temperatures are high (Webb & David, 2002; Zeleke & Bekele, 2004). Our findings agree with Webb and David (2002), Schwalbach *et al*. (2003) and Wesonga *et al*. (2006), who observed seasonal fluctuations in tick burdens, with high tick counts being recorded during the rainy season.

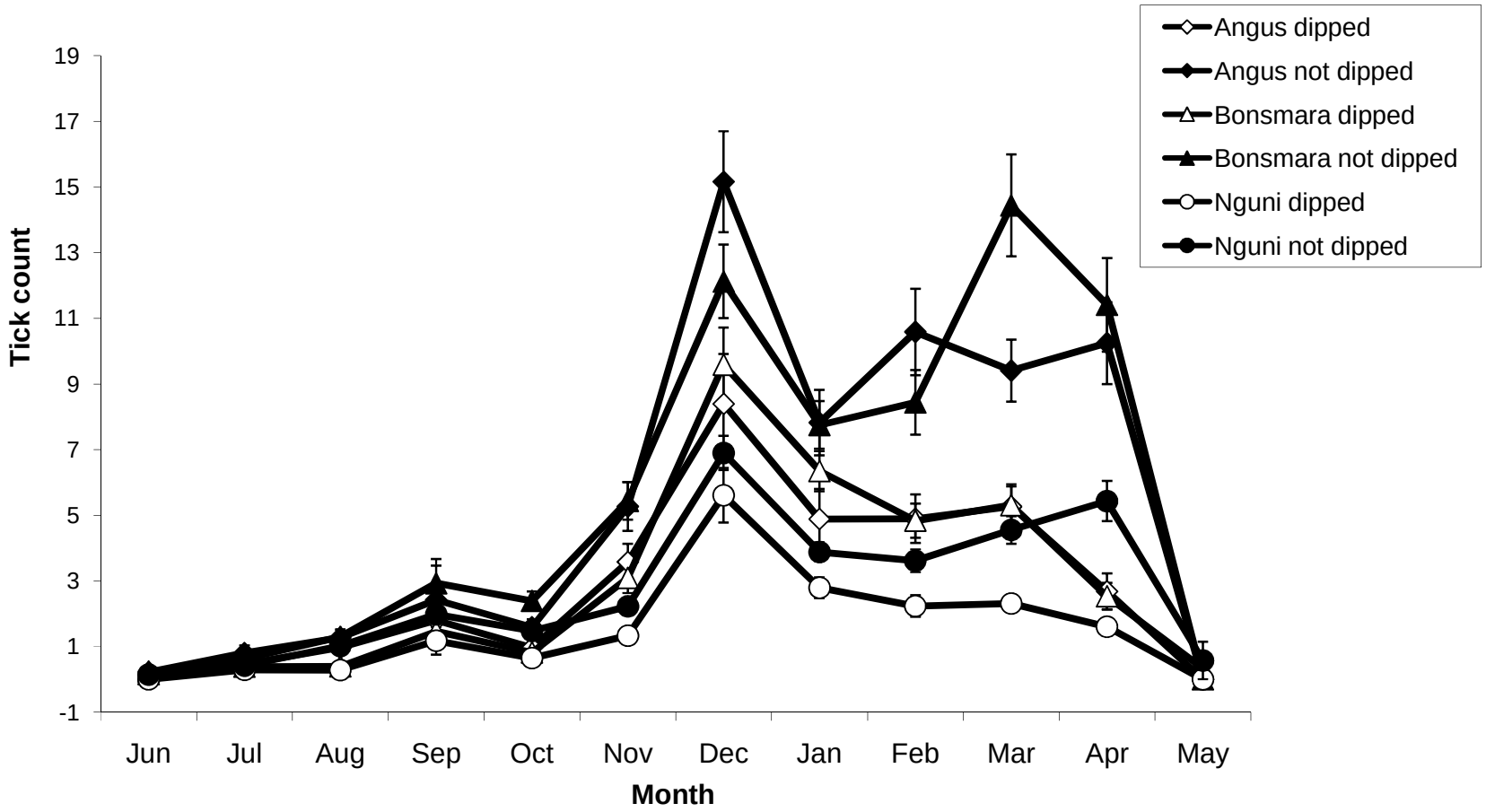

Figure 3.1. Tick counts per position by month in dipped and non-dipped Nguni, Bonsmara and Angus steers.

As shown in Figures 3.1 and 3.2, dipped Nguni steers had the lowest tick counts among the three breeds. The non-dipped Angus steers had the highest tick counts. The observation that Nguni steers haboured the fewest ticks suggests that the indigenous Nguni could be naturally less susceptible to ticks. This agrees with Spickett *et al*. (1989) and Scholtz *et al*. (1991) who reported differences in tick resistance between Hereford, Bonsmara and Nguni cattle in feedlots, with the Nguni having the lowest tick counts. Webb and David (2002) reported similar findings, where Tswana cattle were less susceptible to ticks than the Brahman and Simmental. Some animals consistently carry fewer ticks than others kept in the same environment because of their abilities to respond immunologically to tick infestation (Mattioli *et al*., 2000; Das *et al*., 2005; Johnsson, 2006).

The mechanisms involved in tick tolerance are, as yet, not clearly understood although there is clear evidence of adaptation (Spickett *et al*., 1989). Meltzer (1996) argued that tick avoidance behaviour, skin sensitivity and increased grooming activity by Zebu, Sanga and *Bos indicus* breeds may account for the lower numbers of ticks when compared to tick numbers on exotic *Bos taurus* breeds. The movement of ears and tails may dislodge insects. Brown (1959) noted that Nguni cows moved their ears vigorously when flies irritated them in the region of the head. The flexible and long tail with a well-developed twitch also assisted in removing irritating insects. In the same publication, Brown (1959) investigated the possibility that skin thickness and hair concentration had an effect on tick infestation, but with inconclusive results. However, the higher tick counts on the non-dipped Nguni steers than the dipped Nguni steers imply that dipping still has a role to play in tick control in communal areas.

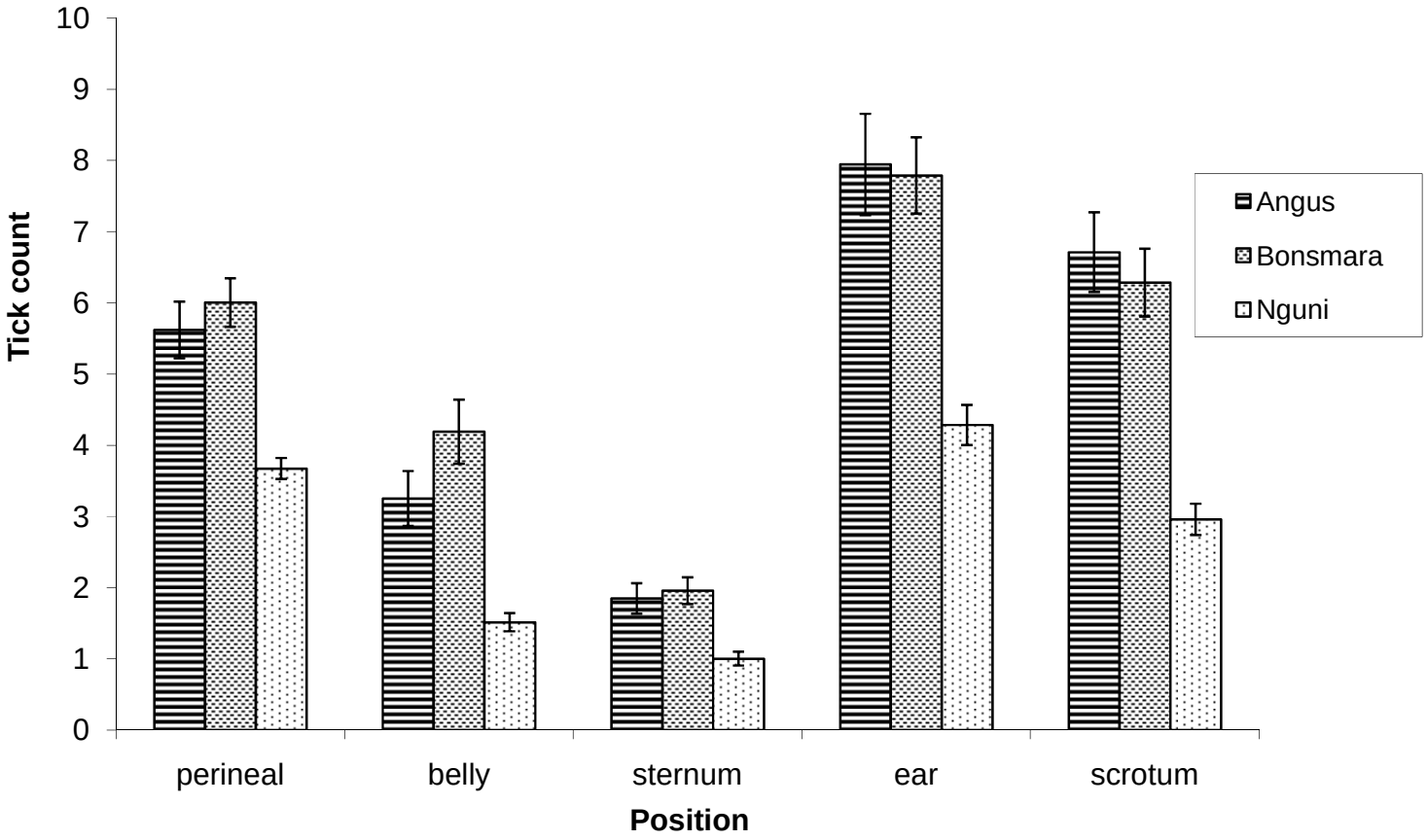

Figure 3.2. Tick counts per position in Nguni, Bonsmara and Angus steers.

Ears had the highest tick infestation ($P < 0.05$), followed by the scrotum and the perineal (Figure 3.2). The belly and sternum had low tick infestations. The presence of more ticks on the ear, scrotum and the perineal area than on the belly and sternum may be ascribed to the fact that ticks prefer warm and moist predilection sites that also provide protection from the environment and predation from birds. These positions are also highly vascularised and have relatively thin skins. The results in the current study agree with Spickett *et al*. (1989), who reported no relationship between hair length and tick count. Our findings, however, are in contrast with Webb and David (2002) in the Tswana, Simmental and the Brahaman, where higher tick counts were observed on the belly, sternum and perineal areas. These positions tend to have long hairs, suggesting sites with longer hair are prone tick infestation.

3.3.2. Liveweights, growth rates and carcass characteristics of steers

There were significant breed effects on liveweight, with the Nguni being the lightest ($P < 0.05$) while the Bonsmara was the heaviest (Figure 3.3). Carcass characteristics of the three breeds are presented in Table 3.1. There were no breed effects ($P > 0.05$) on ADG. Within each breed, the dipped and non-dipped steers had similar liveweights and ADG despite the non-dipped steers having significantly higher ($P < 0.05$) tick counts than the non-dipped ones. There were significant ($P < 0.05$) breed effects on all carcass characteristics. The Bonsmara steers were the heaviest ($P < 0.05$) at slaughter, had the heaviest ($P < 0.05$) carcasses and had the highest dressing percentage while the Nguni steers were the lightest ($P < 0.05$). However, there were no significant ($P > 0.05$) differences in slaughter and carcass characteristics between the Nguni and the Angus steers.

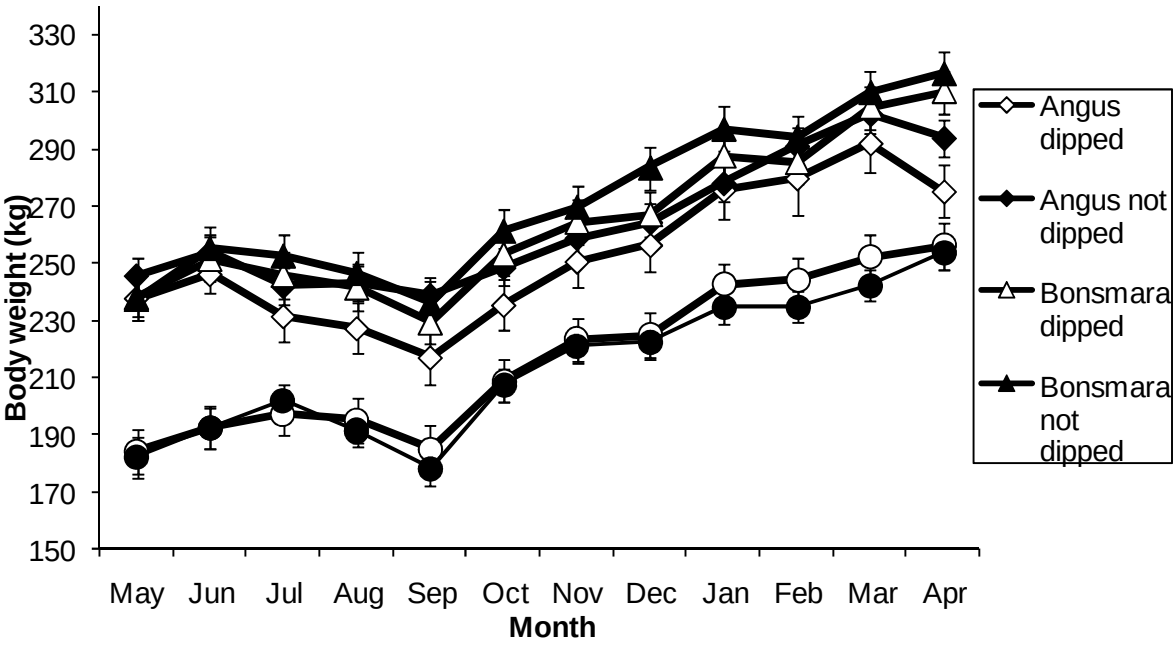

Figure 3.3. Monthly weights of dipped and non-dipped Nguni, Bonsmara and Angus steers.

Table 3.1

Least square means (± s.e.m) of daily gain and carcass characteristics of dipped and non- dipped Nguni, Bonsmara and Angus steers

Breed	Tick control	N	Average daily gain (g/day)	Slaughter weight (kg)	Warm carcass weight (kg)	Dressing Percentage	Eye muscle area (mm^2)
Nguni	Not dipped	25	197 ± 11.9	220 ± 8.0^{a}	111 ± 4.5^{a}	50.3 ± 0.84^{a}	3648 ± 105^{bc}
	Dipped	13	210 ± 12.3	227 ± 10.7^{a}	116 ± 6.1^{ab}	51.0 ± 1.13^{ab}	3858 ± 151.4^{bcd}
Bonsmara	Not dipped	15	241 ± 11.2	265 ± 9.6^{c}	142 ± 5.4^{d}	53.8 ± 1.01^{d}	3996 ± 120.8^{d}
	Dipped	14	220 ± 16.9	254 ± 10.7^{bc}	135 ± 6.1^{cd}	53.4 ± 1.13^{cd}	3988 ± 141.5^{cd}
Angus	Not dipped	6	205 ± 29	240 ± 11.1^{ab}	129 ± 6.3^{bcd}	53.7 ± 1.17^{cd}	3291 ± 210.6^{a}
	Dipped	8	178 ± 33.7	235 ± 12.9^{ab}	123 ± 7.7^{abc}	52.3 ± 1.43^{bc}	3491 ± 170.9^{ab}
Level of significance			NS	*	*	*	*

Means in the same column with different superscripts are different (*P < 0.05), NS = Not significant.

Tick control: Dipped or not dipped, Average daily gain: growth rate from weaning to slaughter, Slaughter weight: weight of steers 24 hours before slaughter; Warm carcass weight: weight of carcass within 20 minutes of slaughter; Dressing percentage: Proportion of warm carcass to liveweight and expressed as a percentage

Nguni steers had the lightest carcasses while the Bonsmara were the heaviest at slaughter. Liveweight is largely a result of size at maturity, biological type and growth rate (Hoving-Bolink *et al*., 1999; Short *et al*., 1999; Alberti *et al*., 2005). The Nguni, however, had similar ADG from weaning to slaughter as the other two breeds. This demonstrates the Nguni's ability to perform well under natural pasture, particularly if the quality of grazing is not that good as is the case in the dry season in most parts of the rural areas of the Eastern Cape. Although tick infestation can lead to body weight losses (Byford, Craig, & Crosby, 1992; Meltzer, 1996; Johnsson, 2006) and can cause substantial economic losses on cattle production (Kivaria, 2006), this was not the case in the current study as the non-dipped steers had similar liveweights and ADG besides having higher tick counts than the dipped steers.

Weight losses of between 0.6 g and 63 g per engorged female tick have been reported and acaricide-treated animals gain more weight than those left untreated (Mattioli *et al*., 2000; Scholtz, 2005; Johnsson, 2006). However, Norval *et al*. (1988) reported no weight losses in Sanga cattle with tick infestation. The Nguni, with its tolerance of ticks, showed less difference in weaning weight between dipped and undipped cattle (Scholtz *et al*., 1991). Further studies to determine tick load threshold of economic importance (tick load level that results in economic losses e.g., decreased live-weight or milk yield) per given breed is warranted.

Carcass weights followed a similar trend to slaughter weight. The Nguni had the lowest dressing percentage while the Bonsmara had the highest dressing percentage. This may be ascribed to the fact that the Nguni steers had horns while the Bonsmara had no horns. The Nguni Society of South Africa discourages the cattle producers from dehorning the Nguni cattle as it considers presence of horns as one of the important features of the Nguni cattle (Hobbs, 2005). Furthermore, dual-purpose breeds have been reported to have lower dressing percentage than pure beef breeds because coefficients of growth for non-carcass fat are higher than those for carcass fat

(Kempster *et al*., 1982; Keane *et al*., 1990; King *et al*., 2006). This may be applicable to the Nguni since it is a multi-purpose breed. Purchas *et al*. (1992) found that carcasses from large framed and late maturing breeds have less fat, higher conformation scores, dressing percentage and proportion of first category cuts. The eye muscle area of the Nguni and the Bonsmara were similar and better than that of the Angus. However, eye muscle area tends to be higher in large framed than in small framed beef breeds (Keane *et al*., 1990; Chambaz *et al*., 2003). Tick control methods did not affect the carcass characteristics of the steers.

The carcass age-fat classes were not affected ($P > 0.05$) by breed. All the carcasses were generally lean. Eighty one per cent of the carcasses were classified as A0 with remaining carcasses being classified as A1. Although management measures to improve the natural pasture, such as rotational grazing, were undertaken in this study, deterioration of grazing lands in the dry season normally occurs, and this is more pronounced in semi-arid areas, where cattle are communally grazed. The steers were generally lean because of the poor condition of the natural pasture that had deteriorated from March. Furthermore, the fact that the steers had no supplement lick could be one of the main reasons for the poor condition as they were in their prime growth phase. It may be argued that the natural pasture may not support the growth of young animals sufficiently to produce carcasses with fat cover. Dietary supplementation using organically or naturally produced material, such as hay from natural pastures or leguminous tree leaves, is recommended.

On a conformation scale of 1 to 5 (with 1 representing a very flat carcass and 5 representing a very round carcass), more carcasses ($P < 0.05$) were classified as 3 than those classified as 2 (Table 3.2). The poorer conformation for the Nguni carcasses than that of the other two breeds was expected since bigger breeds tend to have better carcass conformation than smaller breeds. Continental meat breeds are generally better conformed than traditional breeds

Table 3.2

Frequency of carcass conformation classes in Nguni, Bonsmara and Angus steers

Breed	Frequency (%) conformation class		Total	P value
	2	3		
Aberdeen Angus	5.19 (4)	12.99 (10)	18.18 (14)	0.0425
Bonsmara	2.60 (2)	35.06 (27)	37.66 (29)	
Nguni	14.29 (11)	29.87 (23)	44.16 (34)	
Total	22.08 (17)	77.92 (60)	100 (77)	

Values in parentheses indicate the number of cases.

(Purchas *et al*., 1992; Alberti *et al*., 2005; Vieira, Cerdeño, Serrano, Lavín, & Mantecón, 2006). Continental meat breeds have been selected for meat production over a long period. Despite being an indicator of potential meat yield, carcass conformation is not critical in carcass classification in South Africa.

3.4. Conclusions

Nguni steers were less susceptible to ticks than Bonsmara and Angus steers. While the non-dipped steers had more ticks than the dipped steers, non-dipping did not cause any differences in liveweight and carcass characteristics of the steers. Under adverse conditions, which are common during the dry season in the rural areas of the Eastern Cape, the Nguni had similar weight gains to the large framed beef breeds. Therefore, despite being a smaller and multipurpose breed the Nguni can compete favourably with established breeds in terms of meat production. The Nguni, therefore, has a potential for organic meat production. However, there is need to also compare its meat quality characteristics against these large farmed breeds under natural grazing.

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CHAPTER 4: Relationship between stress responsiveness and meat quality of Nguni, Bonsmara and Aberdeen Angus steers raised on natural pasture

(Submitted to the *Meat Science*)

Abstract

The objective of the current study was to determine the relationship between stress responsiveness and meat quality of Nguni, Bonsmara and Angus steers raised on natural pasture. Thirty steers each of Bonsmara and Angus and 40 weaners of Nguni were kept at the University of Fort Hare Farm for 12 months till slaughter. The *m. longissimus thoracis et lumborum* was sampled for the measurement of meat colour, pH, drip loss, water holding capacity, sarcomere length, cooking loss, myofibrillar fragmentation length and Warner Bratzler shear force (WBSF). Catecholamines and dopamine were measured from urine samples collected approximately 12 minutes post-mortem. Bonsmara steers were the most ($P < 0.05$) stress responsive with respective epinephrine, norepinephrine and dopamine concentrations of 10.8 nmol/mmol, 9.7 nmol/mmol and 14.8 nmol/mmol. Nguni steers were the least ($P < 0.05$) stress responsive, with respective epinephrine, norepinephrine and dopamine concentrations of 5.1 nmol/mmol, 4.3 nmol/mmol and 4.0 nmol/mmol. In the Nguni, L* and catecholamines were negatively correlated ($P < 0.05$) while dopamine was positively correlated ($P < 0.05$) to meat aged for two days. In the Bonsmara, dopamine was positively correlated ($P < 0.05$) to pH while it was negatively correlated ($P < 0.05$) to WBSF for meat aged for two days and cooking losses. No correlations ($P > 0.05$) were found in the Angus. Relationship between stress responsiveness and meat quality depends on breed. There is need to determine the physiological and biochemical changes that take place during stress and glycogen depletion in different breeds.

Keywords: Catecholamines, meat colour, dopamine, glycogen, stress responsiveness

4.1. Introduction

Pre-slaughter glycogen depletion may lead to the inability of muscle to accumulate adequate lactic acid concentration (Kannan, Chawan, Kouakou, & Gelaye, 2002). Consequently, ultimate pH (pHu) increases, which is not ideal for conversion of muscle to meat (Purchas, Yan, & Hartly, 1999). Beef with pHu values higher than 6.0 is undesirable because of its dark colour (Bartos, Franc, Rehák, & Stípková, 1993; Kreikemeier, Unruh, & Eck, 1998; Mounier *et al*., 2006), increased tenderness variation (Silva *et al*., 1999), increased water holding capacity (Apple, Kegley, Galloway, Wistuba, & Rakes, 2005; Zhang *et al*., 2005) and poor palatability (Viljoen, De Kock, & Webb, 2002; Wulf, Emnett, Leheska, & Moeller, 2002). High pH promotes growth of microorganisms which lead to the development of off-odours, and often slime formation (Gardner *et al*., 2001; Gallo, Lizondo, & Knowles, 2003). It is important to determine the factors which affect the depletion of glycogen levels and the mechanism by which glycogen depletion occurs. Breed (King *et al*., 2006), feeding management, nutritional status (Wheeler *et al*., 1996; Sañudo *et al*., 2004; Andersen *et al*., 2005), loading and transportation (Schaefer, Jones, & Stanley, 1997; Mota-Rojas *et al*., 2006), temperament (King *et al*., 2006), pre-slaughter stress and how the animals physiologically respond to stress (O'Neill *et al*., 2006) affects glycogen depletion in animals, and meat quality parameters such as pHu, colour, cooking losses and tenderness.

Animals waiting for slaughter can be stressed by either psychological factors such as restraint, handling, or the novelty of the pre-slaughter environment; or physical factors such as hunger, thirst, fatigue, injury, or thermal extremes. Catecholamines are often implied as the cause of the depletion of glycogen in the pre-slaughter period (O'Neill *et al*., 2006). Dopamine plays a

part in the control of cortisol secretion and may be involved in cortisol-related physiological functions such as stress and metabolism (Ahmadzadeh *et al*., 2006).

When an animal is stressed, there is a rapid release of catecholamines which rapidly mobilise and deplete glycogen (Lacourt & Tarrant, 1985). In a previous report (Muchenje *et al*., 2007), Nguni cattle had darker meat than that of Bonsmara and Angus, although there were no pHu differences among the three breeds. No information is available on the relationship between stress responsiveness and meat quality of Nguni, Bonsmara and Angus cattle raised on natural pasture, as is practiced in rural areas of Southern Africa. While Foury *et al*. (2005) quantified relationships between stress responsiveness and hormones in pigs, no report has sought to establish the strength of the relationship of stress responsiveness and meat quality within beef cattle breeds under natural pasture grazing. There is, therefore, need to evaluate the relationship between stress responsiveness and meat quality of Nguni, Bonsmara and Angus cattle raised under conditions that mimic rural conditions and management systems. The objective of the current study was to determine the relationship between stress responsiveness and meat quality characteristics of Nguni, Bonsmara and Aberdeen Angus when raised on natural pasture. The hypothesis tested was that, under natural grazing, the relationship between stress responsiveness and meat from Nguni steers is similar to the relationship between stress responsiveness and meat from the Bonsmara and Angus breeds.

4.2. Materials and Methods

4.2.1. Animal management, handling and slaughter procedure

Thirty weaners of each of Bonsmara and Angus breed, and 40 weaners of Nguni breed of similar age (around 205 days) were raised at Honeydale Farm, University of Fort Hare till slaughter at 18 months of age. The details of the site where the study was conducted, how the animals were managed and slaughtered were as described by Muchenje *et al*. (2007). The average slaughter weight of the Nguni, Bonsmara and Angus steers were 224, 260 and 238 kg, respectively. The average daily gains were 201, 231 and 189 g/day for Nguni, Bonsmara and Angus, respectively. Animal slaughter and dressing was done following usual commercial procedures at the East London Abattoir.

Urine samples for hormonal determination were collected from the bladder of each animal approximately 12 minutes post-mortem into sample bottles, immediately after evisceration. The sample bottles contained 6 Mol hydrochloric acid to stabilize the catecholamines and dopamine. The samples were then frozen at -20^0C, awaiting analysis.

The m. *longissimus thoracis et lumborum* (LTL) of the left and the right sides were sampled, a day after slaughter, from the 10^{th} rib in the direction of the rump in the following order and amounts for meat quality analyses:

a) 100 mm thick of the anterior side of the left LTL for 2 day aged Warner Bratzler (WBSF) tests,

b) 100 mm thick of the anterior side of the right LTL for 21 days aged tests (WBSF),

c) a 20 mm steak of the near posterior side of the left LTL for myofibrillar length (MFL) on 2 days aged sample,

d) a 20 mm steak of the near posterior side of the left LTL for MFL on 21 days aged sample,

e) a 10 mm steak of the posterior side of the left LTL for sarcomere length (SL),

f) a 15 mm steak of the near posterior side of the left LTL for drip loss in duplicate,

g) a 20 mm steak of the near posterior side of the left LTL for CIE Lab colour measurement,

h) a 20 mm steak of the near posterior side of the left LTL for water holding capacity (WHC) determination.

This amounted to approximately 2.5 kg meat sample per animal. All the meat quality analyses were done on the LTL.

4.2.2. Determination of stress hormone concentration

The urine samples were first hydrolysed before the determination of catecholamines and dopamine (Odink, Sandman, & Schreurs, 1986). Catecholamines and dopamine were extracted from the urine by cation-exchange solid phase extraction, and were determined by the high performance liquid chromatography (HPLC)-method, as described by Gouarne, Foury and Duclos (2004). Briefly, urine samples were loaded on cationic columns and the catecholamines were eluted with boric acid. The eluates were then assayed using HPLC with electrochemical detection with an oxidizing potential of +65V. The catecholamines and dopamine were then quantified against a calibration curve. Concentrations of catecholamines and dopamine are volume-related and for this reason only creatinine-related concentrations were considered in the current study.

4.2.3. Meat quality measurements

Drip loss, pH, sarcomere length (SL), myofibrillar fragmentation length (MFL), meat colour, Warner Bratzler shear force (WBSF) measurement were as described by Muchenje *et al*. (2007).

4.2.3.1. Water-holding capacity measurements

Water holding capacity (WHC) was measured as the amount of water expressed from a minced meat sample (1 g) held under pressure (60 kg pressure) using the filter - paper press method developed by Grau and Hamm (1957). Water holding capacity was calculated using the equation (WHC = 100% - [(outer circle area - inner circle area)/outer circle area] x 100 %).

4.2.3.2. Determination of cooking losses

Percentage cooking loss was calculated as:
[(weight of raw steak after thawing – weight of cooked steak)/weight of raw steak after thawing]x100. It was made up of evaporation and dripping loss during cooking.

4.2.4. Statistical analysis

The effects of breed on catecholamines, dopamine and meat quality traits were analyzed using Generalised Linear Models procedures of SAS (2000). Significance differences between least-square group means were compared using the PDIFF test of SAS (2000). Pearson's correlation coefficients between stress responsiveness hormonal concentration and pH, L*, WBSF values and cooking losses in all steers and within breeds were also determined (SAS, 2000).

4.3. Results and discussion

4.3.1. Stress responsiveness

Epinephrine, norepinephrine and dopamine levels of the three breeds are shown in Table 4.1. There were significant ($P < 0.05$) breed effects on all the stress responsive hormones, with the Bonsmara being the most responsive ($P < 0.05$) and the Nguni being the least responsive. This is in contrast to O'Neill *et al.* (2006) who found that the Nguni crosses were the most responsive to stress when they were compared with the Brahman crosses and the Simmental crosses. Our findings suggest that the Bonsmara steers were the ones that suffered the most pre-slaughter stress. In a study comparing several *Bos taurus* and *Bos indicus* breeds, Koch (2004) reported the Bonsmara to have the lowest levels of stress hormones. The differences in these results may be ascribed to the fact that animals' reactions to stress are governed by a complex interaction of genetic factors and previous experiences (Grandin, 1997, Morme`de, Courvoisier, Ramos, Marissal-Arvy, Ousova, & De´saute´s, 2002; Mounier *et al*., 2006). During the growth phase,

Table 4.1

Least square means and standard errors of means (in parenthesis) of urinary catecholamine and dopamine outputs from Nguni, Bonsmara and Aberdeen Angus steers

	Breed		
Catecholamine	Nguni	Bonsmara	Angus
n	34	29	14
Norepinephrine (nmol/mmol)	4.3 (1.03) [a]	9.7 (1.36) [b]	6.5 (1.98) [c]
Epinephrine (nmol/mmol)	5.1 (1.30) [a]	10.8 (1.68) [b]	6.7 (3.21) [a]
Dopamine (nmol/mmol)	4.0 (0.27) [a]	14.8 (2.77) [b]	7.2 (2.2) [c]

Means in the same row with different superscripts are significantly different at $P < 0.05$.

Bonsmara steers were the most unsettled group while the Nguni steers were the calmest during handling. Cattle with a very excitable temperament may have greater difficulty adapting to repeated non-painful handling procedures than cattle with a calmer temperament. Our findings show that different types of animals have differing physiological and behavioral reactions to the same procedure (Lanier, Friend, Bushong, Knabe, Champney, & Lay, 1995). Animals with a calm temperament may adapt more easily and become less stressed with repeated handling treatments and animals with a very excitable temperament may become increasingly stressed with each repeated handling treatment.

However, studies to determine the amount of stress on farm animals during routine handling and transport often have highly variable results and are difficult to interpret (Grandin, 1997). Stanger, Ketheesan, Parker, Coleman, Lazzaroni and Fitzpatrick (2005) suggested that animals that withstand the environmental stressors of a harsh environment may not show higher concentrations of stress hormones under a potentially stressful environment. Genetic factors, including temperament, influence the degree to which animals respond to stress (Grandin, 1997; Morme`de *et al*., 2002; Fazio & Ferlazzo, 2003). It can, therefore, be noted that animals react differently to stress conditions and stress responsiveness is complex. The effects of stress responsiveness to glycogen depletion, and its resultant effect on meat quality parameters such as pH, colour, tenderness and cooking losses is, therefore, likely to be highly variable.

4.3.2. Meat quality

Table 4.2 shows the meat quality characteristics of Nguni, Bonsmara and Angus steers. Meat lightness (L*) was the only meat quality trait that was significantly ($P < 0.05$) affected by

Table 4.2

Least square means and standard errors of means (in parenthesis) of meat quality characteristics of Nguni, Bonsmara and Aberdeen Angus steers

Meat quality characteristic	Breed		
	Nguni	Bonsmara	Angus
n	34	29	14
Lightness (L*)	37.0 (0.54) [a]	40.1 (0.53) [b]	40.4 (0.65) [b]
Redness (a*)	14.7 (0.45)	14.8 (0.37)	15.9 (0.45)
Yellowness (b*)	6.1 (0.27)	6.3 (0.18)	6.9 (0.25)
Colour saturation	15.9 (0.50)	16.1 (0.40)	17.4 (0.50)
Sarcomere length (µm)	1.6 (0.03)	1.6 (0.02)	1.6 (0.03)
WBSF2 (N)	42.1 (3.33)	46.1 (3.14)	42.1 (3.04)
WBSF21 (N)	31.4 (1.76)	34.3 (1.67)	36.3 (1.37)
MFL2 (µm)	28.2 (0.79)	30.8 (1.16)	29.3 (1.37)
MFL21 (µm)	22.9 (0.49)	21.9 (0.61)	21.4 (1.13)
pH	5.8 (0.06)	5.7 (0.04)	5.6 (0.02)
Drip loss (%)	2.0 (0.11)	1.9 (0.11)	1.8 (0.11)
Water holding capacity	0.35 (0.016)	0.30 (0.013)	0.32 (0.038)
Cook loss 2 (%)	24.8 (1.07)	24.3 (0.42)	25.3 (0.49)
Cook loss 21 (%)	23.6 (0.48)	24.1 (0.45)	24.9 (0.62)

Means in the same row with different superscripts are significantly different at $P < 0.05$; MFL2 - Myofibrillar fragment length for meat aged for two days; MFL21-Myofibrillar fragment length for meat aged for 21 days; WBSF2-Warner Bratzler value for meat aged for two days; WBSF21-Warner Bratzler value for meat aged for 21 days; Cook loss 2 (%) - Cooking loss after aging for 2 days; Cook loss 21 (%) - Cooking loss after aging for 21 days

breed. The L* value for Nguni meat was the lowest ($P < 0.05$) while that of the Angus was the highest ($P < 0.05$). The appearance characteristics, except lightness L*, were similar in the three breeds, which agree the findings of Muchenje *et al*. (2007). Differences in meat colour have been associated with variations in intramuscular fat and moisture content, age dependent changes in muscle myoglobin content (Lawrie, 1974), the pHu of the muscle (Hector, Brew-Graves, Hassen, & Ledward, 1992), with higher pHu being associated with dark cuts and vice versa. However, Priolo *et al*. (2001) concluded that the evidence on the causes of variation was mixed. In addition, the steers used in the current study were of similar age.

The darker meat produced by the Nguni steers in comparison to the improved breeds agrees with O'Neill *et al.* (2006). Differences in meat colour are not fully understood. O'Neill *et al.* (2006), however, observed that Nguni cattle released more catecholamines than exotic breeds, during the pre-slaughter period, causing the depletion of glycogen. In this study, although the Nguni had darker meat, it released the least catecholamines while the Bonsmara released the highest catecholamines. An increase in pHu does not necessarily result in tougher meat as other parameters with regard to meat tenderness may be involved. As shown in Table 4.2, the pHu (< 6.2) and L* values (> 33) were within the expected ranges (Lawrie, 1974; Diaz, Anaya, Gonzalez, Sanchez-Escalante, & Torrescano, 2006) that would not result in dark firm dry (DFD) meat.

The WBSF values, MFL and sarcomere lengths were similar ($P > 0.05$) among the breeds, which agrees with Muir, Wallace, Dobbie and Bown (2000), Revilla and Vivar-Quintana (2006) and Muchenje *et al*. (2007) in which the tenderness of meat from steers of different breeds was similar when slaughtered at the same age. Strydom *et al*.

(2000; 2001) reported no differences in WBSF values among Nguni and Bonsmara steers raised in a feedlot. Sañudo *et al.* (2004), however, reported that differences between breed types for most WBSF values were more pronounced at the lower carcass weight than at higher carcass weights. It has also been reported that different breeds had a wide spectrum of fibre types in muscles, but these were not always reflected by differences in instrumental analyses using WBSF or sensory panels (Sañudo *et al*., 2004).

As in our previous study (Muchenje *et al*., 2007), meat tenderness improved ($P < 0.05$) with aging of the muscle. However, in meat from the Angus steers, there was no difference ($P < 0.05$) in WBSF values after aging for two and 21 days, possibly due to almost complete aging of the Angus meat by day two. Muir *et al*. (2000) reported no differences in WBSF measurements in meat tenderness between breeds when compared at the same age, with ageing complete by six days after slaughter. Stolowski *et al*. (2004) found that aging can improve WBSF values up to 14 days; and, postmortem aging beyond 14 d may not be effective in improving WBSF of steaks from cattle with large *Bos indicus* influence. Meat tenderness is a function of the collagen content, heat stability and the myofibrillar structure of muscle, though these appear to be affected mainly by the rate of growth of the cattle rather than breed *per se* (Muir *et al*., 2000; Monson *et al*., 2005). The myofibrillar component of tenderness can also be influenced by the calpain proteolytic enzyme system during ageing of the carcass post-mortem. However, Wheeler and Koohmaraie (1991) suggested that the myofibrillar component could be a more important factor than the connective tissue characteristics in influencing meat tenderness. This could be applicable in this study where the animals were slaughtered at a young age, implying that the muscles were likely to be low in connective tissue.

The pHu values, ranging from 5.6 in meat from Angus steers to 5.8 in meat from Nguni steers, were within the expected range and similar to those reported in our previous study (Muchenje *et al*., 2007) and by other authors (Beltran, Jaime, Santolaria, Sañudo, Alberti, & Roncales, 1997; Silva *et al*., 1999; Revilla & Vivar-Quintana, 2006). However, as in our previous study (Muchenje *et al*., 2007) no breed effects were observed on pH in the current study. This agrees with previous reports (Hoving-Bolink *et al*., 1999; Chambaz *et al*., 2003; Monson, Sañudo, & Sierra, 2004), where no breed differences ($P > 0.05$) on pHu were observed.

There were no breed effects on cooking losses in the current study. However the cooking losses were lower than those of Razminowicz *et al*. (2006) in pasture fed steers which averaged 30 %. During heating most drastic changes occur in meat, such as shrinkage and hardening of tissue and release of cooking juice. These changes are caused by structural changes of myofibrillar proteins and of membrane structures (Razminowicz *et al*., 2006).

4.3.3. Relationship between stress responsiveness and meat quality

Table 4.3 shows the correlation coefficients between stress responsiveness hormonal concentration and pHu, L*, tenderness and cooking losses. Only the Nguni showed a negative relationship ($P < 0.05$) between catecholamines and L*. The Nguni also showed a positive relationship ($P < 0.05$) between dopamine and WBSF of meat aged for two days. In the Bonsmara steers, there were significant positive correlations between dopamine and pHu. There were also negative relationships between dopamine,

Table 4.3

Correlations between stress responsiveness hormones from urine and meat lightness (L*), pH, tenderness and cooking loss of meat from all, Nguni, Bonsmara and Angus steers

Meat Quality characteristic	Epinephrine				Norepinephrine				Dopamine			
	All	Nguni	Bonsmara	Angus	All	Nguni	Bonsmara	Angus	All	Nguni	Bonsmara	Angus
Lightness (L*)	-0.13	-0.65**	-0.07	-0.77	0.00	-0.52*	0.04	-0.82	0.09	-0.14	-0.39	0.54
pH	-0.10	0.02	0.00	0.32	0.09	0.13	-0.01	0.41	-0.04	-0.22	0.54*	-0.20
WBSF2[a]	0.11	0.21	-0.15	0.84	0.14	0.13	0.00	0.79	-0.10	0.53*	-0.52*	-0.80
WBSF21[b]	0.20	0.42	-0.23	0.36	0.12	0.13	-0.16	0.38	0.12	0.29	-0.13	-0.73
Cook loss 2[c]	-0.13	-0.29	0.09	0.55	-0.10	-0.30	-0.10	0.47	-0.12	0.00	-0.62*	-0.57
Cook loss 21[d]	0.04	-0.09	0.22	-0.22	0.00	-0.29	0.19	-0.26	-0.18	-0.02	-0.61*	0.61

NB. Correlation coefficients between meat lightness (L*) and pH for all steers was -0.43 ($P < 0.001$), for Nguni steers was -0.21 ($P = 0.22$), for Bonsmara steers was -0.58 ($P < 0.001$), and for Angus steers was -0.6 ($P = 0.02$). Significantly correlated at * $P < 0.05$, ** $P < 0.01$, ***$P < 0.001$; WBSF2[a], Warner Bratzler value for meat aged for two days; WBSF21[b], Warner Bratzler value for meat aged for 21 days; Cook loss 2[c] (%), Cooking loss after aging for 2 days; Cook loss 21[d] (%), Cooking loss after aging for 21 days

and WBSF for meat aged for two days, and cooking losses. In Angus steers, there were no relationships between stress responsiveness hormonal concentrations and all the meat quality traits. As expected, there was a significant negative correlation between pHu and L* in Bonsmara and Angus. However, there was no relationship ($P > 0.05$) between pHu and L* in the Nguni steers. Furthermore, the Nguni meat was the darkest ($P < 0.05$) among the three breeds (Table 4.2).

The results found in this study confirm the varied nature of stress responsiveness of animals (Grandin, 1997; Koch, 2004) and its effects on meat quality, especially, pH, L* and tenderness. It is not clear why the Nguni steers which had the darkest meat among the three breeds had the lowest levels of catecholamines and dopamine. Furthermore, the Nguni was the only breed whose meat had significant relationships between catecholamines and L*, dopamine and WBSF for meat aged for two days while it did not have a relationship between pH and L*. It is expected that sympathetic activation before slaughter increases muscle glycogenolysis and, therefore, reduces lactic acid production post-mortem and meat acidification (Fernandez & Tornberg, 1991). This is expected to result in high pH, darker and tougher meat (O'Neill *et al.*, 2006). Foury *et al*. (2005) found catecholamine levels to be positively correlated with pork pH measured 24 hours after slaughter. However, it is worth noting that this relationship varies to a large extent among muscles, depending on their metabolic properties and their sensitivity to catecholamines (Larzul, Le Roy, Monin, & Sellier, 1998).

Differences in meat colour have also been associated with variations in intramuscular fat, moisture content and age dependent changes in muscle myoglobin content (Purchas *et al.*, 1999). Although correlations between meat colour and

intramuscular fat and moisture content were not determined in the current study, they were significant correlations in our previous study (Muchenje *et al*., 2007). Our results imply that the darker meat colour in Nguni could be attributed to some other biochemical and physiological factors as opposed to glycogen depletion and rise in pH. O'Neill *et al.* (2006) reported a marginally slower decrease in carcass pH in Nguni crosses as compared to Brahman crosses and Simmental crosses when they were raised in a feedlot. It may be that a marginal change in pH in Nguni meat may have a higher impact on L* as compared to the impact of a similar change in other breeds. Such changes may not be so significant as to cause any correlations between pH and L* in the Nguni breed. It is also important to determine whether the variations found in urinary levels of hormones result from differences in basal secretion or in the intensity of the response to pres-laughter stress or in both (Foury *et al*., 2005). There is need to conduct research on nutritional status, urinary hormonal levels, the biochemical changes that take place during glycogen depletion, glycolytic potential, changes in pH and their effect on colour changes in Nguni cattle raised on natural pasture to understand the complex nature of the relationships.

The findings of this study imply that the relationship between stress responsiveness hormones and pH, L*, tenderness and cooking may be breed-dependent. This agrees with Grandin (1997) who argued that genetic factors, including temperament, influence the degree to which animals respond to stress. The fact that the Bonsmara steers were highly temperamental can be attributed to high levels of dopamine, which, in turn, stimulates the release of cortisol when an animal is stressed. Zavy, Juniewicz, Phillips and Von Tungeln (1992) found that the Brahman cross cattle had higher cortisol levels when restrained in a squeeze chute than English crosses.

Results in the current study suggest that the relationship between stress responsiveness and glycogen depletion and meat quality is complex. Furthermore, the relationships between cortisol and catecholamine levels on one hand and structural measures like muscle yield on the other hand demonstrate that stable differences in the HPA axis and SNS activity are probably involved (Foury *et al*., 2005). In pigs, a high correlation between basal urinary cortisol level (urine collected in the farm) and post-stress level measured after transportation was reported (Morme`de *et al*., 2002), suggesting that the levels measured at slaughter may indeed reflect basal HPA axis activity. Determining the effects of stress responsiveness on glycogen and meat quality needs to be done in relation to breed (Zavy *et al*. 1992; King *et al*., 2006), feeding management, nutritional status (Wheeler *et al*. 1996, Andersen *et al*., 2005), transporting (Schaefer *et al*., 1997), temperament (King *et al*., 2006), the animals' previous experiences (Grandin, 1997, Mounier *et al*., 2006), basal levels measured when urine is collected in the farm and levels measured after slaughter (Foury *et al*., 2005).

4.4. Conclusions

Catecholamines can be used as good indicators of L* and tenderness after aging for two days in Nguni steers, but not for pH, tenderness after aging for longer periods and cooking losses. Dopamine can be used as a good indicator of pH, tenderness at two days and cooking losses in Bonsmara steers, but not L* and tenderness after aging for longer periods. Neither catecholamines nor dopamine are good indicators of meat quality in Angus steers. While levels of catecholamines and dopamine can be useful indicators of

pH, L*, tenderness and cooking losses their interpretation tends to be complex and breed dependent. There is need, however, to determine the biochemical changes that take place in relation to stress responsiveness and the depletion of glycogen and its effects on meat quality of the Nguni cattle raised on natural pasture. Sensory evaluations and fatty acid profiles of the Nguni cattle raised on natural pasture also need to be compared to Angus and Bonsmara cattle breeds under similar conditions.

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CHAPTER 5: Relationships among meat quality characteristics of Nguni, Bonsmara and Aberdeen Angus steers raised on natural pasture in the Eastern Cape, South Africa

(Sumitted to *Livestock Science*)

Abstract

The objective of the current study was to determine within breed correlations among quality traits of meat from Nguni, Bonsmara and Angus steers. Thirty seven-month old weaners of each of Bonsmara and Angus, and 40 seven-month old weaners of Nguni were kept at the University of Fort Hare Farm for 12 months till slaughter. At slaughter, carcasses were electrically stimulated. The *m. longissimus thoracis et lumborum* was sampled for the measurement of meat colour, pH, drip loss, water holding capacity, sarcomere length, cooking loss, myofibrillar fragmentation length (MFL) and Warner Bratzler shear force (WBSF). There were significant ($P < 0.05$) correlations among some meat quality traits. There were significant ($P < 0.05$) correlations between WBSF values of meat aged for two and 21 days in Nguni and Bonsmara, but not in Angus. Relationships among most quality traits of meat breed dependent and therefore use of correlation information across breeds should be done with caution.

Keywords: Colour, cooking loss, correlations, pH, tenderness, water holding capacity

5.1. Introduction

Changes in meat quality affect relationships among different meat quality traits. For example, breed (King *et al*., 2006), feeding management, nutritional status (Wheeler *et al*., 1996; Sañudo *et al*., 2004; Andersen *et al*., 2005), affect glycogen depletion, and meat quality parameters such as ultimate pH (pHu), colour, cooking losses and

tenderness. Beef with pHu values higher than 6.0 is undesirable because it is dark (Bartos *et al*., 1993; Kreikemeier *et al*., 1998; Mounier *et al*., 2006), has increased tenderness variation which is not desirable to the consumer (Silva *et al*., 1999), has increased water holding capacity (Apple *et al*., 2005; Zhang *et al*., 2005), poor palatability (Viljoen *et al*., 2002; Wulf *et al*., 2002), and growth of microorganisms to unacceptable levels with development of off-odours, and often slime formation (Gardner *et al*., 2001; Gallo *et al*., 2003). Vestergaard *et al*. (2000) and Baublits *et al*. (2004) reported that forage-fed beef has less marbling and has darker lean colour than grain-fed beef. However, Bidner, Schupp, Montgomery and Carpenter (1981) reported no differences in quality grades and marbling scores between carcasses from forage-fed and maize-supplemented forage steers.

Most studies on meat quality on the Nguni cattle have been on feedlot systems under commercial farming conditions (Gertenbach & Henning, 1995; Strydom *et al*., 2000; 2001). Our earlier study on natural grazing systems simulating communal areas (Muchenje *et al*., 2007) found that there were no breed effects on meat quality and there were breed differences on correlations among most characteristics. Knowledge of relationships among meat quality characteristics can be used to predict meat characteristics that are expressed much later postmortem, such as tenderness, shelf life, water holding capacity (WHC) and cooking losses which can be indicated on the basis of the knowledge on pH soon after slaughter. Razminowicz *et al*. (2006) used cooking loss determination to estimate water holding capacity (WHC) of meat. The relationships among meat quality traits may, however, differ depending on breeds (King *et al*., 2006;

Muchenje *et al*., 2007), feeding management, nutritional status (Wheeler *et al*., 1996; Andersen *et al*., 2005).

In our earlier study (Muchenje *et al*., 2007) correlations among several meat quality traits were determined, but we did not consider correlations among those traits and cooking losses and WHC, which are also important meat quality traits. There is, therefore, need to determine relationships among WHC and cooking losses and other meat quality characteristics from different cattle breeds in particular production systems such as those that mimic communal conditions and management systems. The objective of the current study was to determine correlations among cooking losses, WHC and other meat quality traits within Angus, Bonsmara and Nguni cattle breeds. The hypothesis tested was that, under natural grazing, correlations among quality traits of meat from Nguni steers are similar to those of meat from the Bonsmara and Angus cattle breeds.

5.2. Materials and Methods

5.2.1. Animal management, handling and slaughter procedure

Thirty weaners of each of Bonsmara and Angus breed, and 40 weaners of Nguni breed of similar age (around 205 days) were raised at Honeydale Farm, University of Fort Hare till slaughter at 18 months of age. The details of the site where the study was conducted, how the animals were managed and slaughtered were as described by Muchenje *et al*. (2007). The average slaughter weight of the Nguni, Bonsmara and Angus steers were 224, 260 and 238 kg, respectively. The average daily gains were 201, 231 and

189 g/day for Nguni, Bonsmara and Angus, respectively. Animal slaughter and dressing was done following usual commercial procedures at the East London Abattoir. The m. *longissimus thoracis et lumborum* (LTL) of the left and right sides was sampled, a day after slaughter, from the 10^{th} rib in the direction of the rump in the following order and amounts for meat quality analyses:

a) 100 mm thick of the anterior side of the left LTL for 2 day aged Warner Bratzler (WB) tests,

b) 100 mm thick of the anterior side of the right LTL for 21 days aged (WB) tests,

c) a 20 mm steak of the near posterior side of the left LTL for myofibrillar length (MFL) on 2 days aged sample,

d) a 20 mm steak of the near posterior side of the left LTL for MFL on 21 days aged sample,

e) a 10 mm steak of the posterior side of the left LTL for sarcomere length (SL),

f) a 15 mm steak of the near posterior side of the left LTL for drip loss in duplicate,

g) a 20 mm steak of the near posterior side of the left LTL for CIE Lab colour measurement,

h) a 20 mm steak of the near posterior side of the left LTL for water holding capacity (WHC) determination.

This amounted to approximately 2.5 kg meat sample per animal. All the meat quality analyses were done on the LTL.

5.2.2. Meat quality measurements

Drip loss, pH, sarcomere length (SL), myofibrillar fragmentation length (MFL), meat colour, Warner Bratzler shear force (WBSF) measurement were as described by Muchenje *et al*. (2007). Water holding capacity (WHC) and cooking loss determination were as described in Sections 4.2.3.1 and 4.2.3.2 respectively.

5.2.3. Statistical Analysis

Pearson's correlation coefficients among meat quality characteristics in all steers and within breeds were determined in SAS (2000).

5.3. Results and discussion

Summary statistics of quality traits of meat from the Nguni, Bonsmara and Angus steers are presented in Tables 5.1, 5.2 and 5.3 respectively.

5.3.1. Meat quality correlations

As shown in Tables 5.4 to 5.8, most meat quality traits within each breed were not ($P > 0.05$) correlated. The Angus steers had the fewest significant ($P < 0.05$) correlations among meat quality traits. There were no ($P < 0.05$) correlations between sarcomere

Table 5.1

Summary statistics of the meat quality characteristics of meat from Nguni steers (n=33)

Meat quality characteristic	Mean	Std	Minimum	Maximum
Lightness (L*)	36.9	3.14	29.1	44.7
Sarcomere length (µm)	1.6	0.17	1.2	2.0
WBSF2 (N)	42.1	19.50	11.2	101.5
WBSF21 (N)	31.6	10.29	16.3	76.2
MFL2 (µm)	28.0	4.60	21.3	40.7
MFL21 (µm)	22.8	2.86	17.9	29.3
pH	5.8	0.35	5.5	6.7
Drip loss (%)	2.0	0.60	1.3	3.9
Water holding capacity	0.36	0.068	0.20	0.51
Cook loss 2 (%)	24.7	6.27	15.0	54.1
Cook loss 21 (%)	23.5	2.76	18.7	29.3

Std – Standard deviation; MFL2 - Myofibrillar fragment length for meat aged for two days; MFL21-Myofibrillar fragment length for meat aged for 21 days; WBSF2-Warner Bratzler value for meat aged for two days; WBSF21-Warner Bratzler value for meat aged for 21 days; Cook loss 2 (%) - Cooking loss after aging for 2 days; Cook loss 21 (%) - Cooking loss after aging for 21 days

Table 5.2

Summary statistics of the meat quality characteristics of meat from Bonsmara steers (n =29)

Meat quality characteristic	Mean	Std	Minimum	Maximum
Lightness (L*)	40.1	2.83	35.6	46.8
Sarcomere length (µm)	1.6	0.12	1.3	1.9
WBSF2 (N)	46.1	17.05	16.4	87.2
WBSF21 (N)	34.0	8.94	17.84	71.9
MFL2 (µm)	30.8	6.23	21.0	46.8
MFL21 (µm)	21.9	3.31	16.8	27.8
pH	5.7	0.23	5.5	6.5
Drip loss (%)	1.9	0.60	1.1	3.2
Water holding capacity	0.30	0.052	0.18	0.39
Cook loss 2 (%)	24.3	2.28	18.4	29.5
Cook loss 21 (%)	24.1	2.40	17.9	28.2

Std – Standard deviation; MFL2 - Myofibrillar fragment length for meat aged for two days; MFL21-Myofibrillar fragment length for meat aged for 21 days; WBSF2-Warner Bratzler value for meat aged for two days; WBSF21-Warner Bratzler value for meat aged for 21 days; Cook loss 2 (%) - Cooking loss after aging for 2 days; Cook loss 21 (%) - Cooking loss after aging for 21 days

Table 5.3

Summary statistics of the meat quality characteristics of meat from Angus steers (n = 14)

Meat quality characteristic	Mean	Std	Minimum	Maximum
Lightness (L*)	40.4	2.44	38.1	46.2
Sarcomere length (µm)	1.6	0.12	1.3	1.7
WBSF2 (N)	42.1	11.47	28.4	74.5
WBSF21 (N)	35.9	4.99	28.4	42.7
MFL2 (µm)	29.3	5.13	22.8	41.9
MFL21 (µm)	21.4	4.23	15.5	29.1
pH	5.6	0.08	5.5	5.8
Drip loss (%)	1.8	0.43	1.4	2.9
Water holding capacity	0.31	0.075	0.20	0.37
Cook loss 2 (%)	25.3	1.85	20.8	27.5
Cook loss 21 (%)	24.9	2.32	21.7	30.3

Std – Standard deviation; MFL2 - Myofibrillar fragment length for meat aged for two days; MFL21-Myofibrillar fragment length for meat aged for 21 days; WBSF2-Warner Bratzler value for meat aged for two days; WBSF21-Warner Bratzler value for meat aged for 21 days; Cook loss 2 (%) - Cooking loss after aging for 2 days; Cook loss 21 (%) - Cooking loss after aging for 21 days

Table 5.4

Linear relationship (r) between sarcomere length (SL) and some meat quality traits of the *Longissimus thoracis et lumborum* muscle of Nguni, Bonsmara and Angus steers.

Meat quality trait	r (Nguni)	r (Bonsmara)	r (Angus)
Lightness (L*)	0.40*	-0.05	0.17
pH	-0.40*	0.12	0.33
Cook loss for meat aged for 2 days	-0.11	0.12	-0.03
Cook loss for meat aged for 21 days	0.21	0.12	-0.34
Water holding capacity (WHC)	-0.27	-0.31	-0.31
Drip loss	-0.23	-0.31	0.11
Myofibrillar fragmentation length for meat aged for two days (MFL2)	-0.14	-0.44*	-0.30
Myofibrillar fragmentation length for meat aged for 21 days (MFL21)	-0.15	-0.36	-0.32
Warner Bratzler value for meat aged for two days (WBSF2)	0.02	-0.17	-0.47
Warner Bratzler value for meat aged for 21 days (WBSF21)	-0.02	-0.28	0.11

Significantly correlated at * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Table 5.5

Linear relationship (r) between Warner-Bratzler shear forces for meat aged for two (WBSF2) and 21 days (WBSF21) and some meat quality traits of the *Longissimus thoracis et lumborum* muscle of Nguni, Bonsmara and Angus steers.

Meat quality trait	r (Nguni)		r (Bonsmara)		r (Angus)	
	WBSF2	WBSF21	WBSF2	WBSF21	WBSF2	WBSF21
Lightness (L*)	0.01	-0.14	-0.09	0.06	0.08	-0.07
pH	-0.47**	-0.38*	-0.23	-0.25	-0.44	-0.22
Cook loss for meat aged for 2 days	0.04	-0.02	0.24	0.00	0.47	0.33
Cook loss for meat aged for 21 days	0.39*	0.24	0.04	0.00	0.46	-0.37
Water holding capacity (WHC)	-0.26	-0.35	0.01	-0.25	-0.22	0.78
Drip loss	0.37*	0.36*	0.16	0.28	-0.01	0.19
Myofibrillar fragmentation length for meat aged for two days (MFL2)	0.64***	0.28	0.20	0.14	0.29	0.26
Myofibrillar fragmentation length for meat aged for 21 days (MFL21)	0.15	0.14	0.32	0.24	0.55*	0.04

Correlation coefficients between WBSF2 and WBSF21: Nguni = 0.71***, Bonsmara = 0.53**, Angus = 0.25

Significantly correlated at * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Table 5.6

Linear relationship (r) between cooking losses for meat aged for two (Cook2) and 21 days (Cook21) and some meat quality traits of the *Longissimus thoracis et lumborum* muscle of Nguni, Bonsmara and Angus steers.

Meat quality trait	r (Nguni)		r (Bonsmara)		r (Angus)	
	Cook2	Cook21	Cook2	Cook21	Cook2	Cook21
Lightness (L*)	-0.06	0.27	0.63***	0.77***	0.08	0.38
pH	-0.10	-0.61***	-0.57**	-0.67***	-0.30	-0.64*
Water holding capacity (WHC)	-0.38	-0.38	-0.63*	-0.57*	-0.41	-0.89
Drip loss	0.15	0.27	0.53**	0.50**	0.13	0.34
Myofibrillar fragmentation length for meat aged for two days (MFL2)	0.16	0.36*	0.35	0.28	0.25	0.31
Myofibrillar fragmentation length for meat aged for 21 days (MFL21)	-0.10	0.07	0.13	0.04	0.22	0.63*

Correlation coefficients between Cook2 and Cook21: Nguni = 0.14, Bonsmara = 0.83***

, Angus = 0.28

Significantly correlated at * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Table 5.7

Linear relationship (r) between water holding capacity (WHC) and some meat quality traits of the *Longissimus thoracis et lumborum* muscle of Nguni, Bonsmara and Angus steers.

Meat quality trait	r (Nguni)	r (Bonsmara)	r (Angus)
Lightness (L*)	-0.73***	-0.59*	-0.21
pH	0.32	0.60*	0.54
Drip loss	-0.10	-0.26	-0.12
Myofibrillar fragmentation length for meat aged for two days (MFL2)	-0.14	-0.12	0.46
Myofibrillar fragmentation length for meat aged for 21 days (MFL21)	-0.34	-0.12	-0.13

Significantly correlated at * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Table 5.8

Linear relationship (r) between lightness (L* value) and pH and some meat quality traits of the *Longissimus thoracis et lumborum* muscle of Nguni, Bonsmara and Angus steers.

Meat quality trait	r (Nguni)		r (Bonsmara)		r (Angus)	
	L* value	pH	L* value	pH	L* value	pH
Drip loss	0.07	-0.06	0.52**	-0.49**	0.74**	-0.48
Myofibrillar fragmentation length for meat aged for two days (MFL2)	0.02	-0.24	0.31	-0.23	-0.10	-0.42
Myofibrillar fragmentation length for meat aged for 21 days (MFL21)	0.27	0.30	0.16	0.04	0.31	0.22

Correlation coefficients between L* value and pH: Nguni = -0.22, Bonsmara = -0.58***, Angus = -0.60*

Significantly correlated at * P < 0.05; ** P < 0.01; *** P < 0.001.

length (SL) and Warner-Bratzler shear force (WBSF) values (Table 5.4). This is unexpected since there are usually negative correlations between SL and WBSF values due to the fact that muscles with short SL are generally tough (Strydom *et al*., 2000; Revilla & Vivar-Quintana, 2006). In an earlier study (Muchenje *et al*., 2007), we found more negative correlations between SL and WBSF values in Nguni and Bonsmara indicating that muscles with short SL tend to be tougher. The absence of correlations between SL and WBSF may ascribed to electrical stimulation of the steers at slaughter that could have resulted in less variability in SL (the coefficient of variation of SL in this study was 9.2 %). In meat from the Nguni steers SL was positively correlated ($P < 0.05$) to lightness (L* value) and negatively correlated to and negatively correlated ($P < 0.05$) to pH. The reason for this kind of relationship is not clear.

The negative correlation ($P < 0.05$) between SL and the myofibrillar fragmentation length for meat aged for two days (MFL2) is as expected since longer SL and short MFL indicate meat that less tough (Wheeler *et al*., 1996). It is, however, not clear there whey there was no ($P > 0.05$) significant relationship between SL and MFL2 in the other two breeds, and between SL and MFL21 in all the three breeds.

Except for MFL2 in Nguni and MFL21 in Angus, there were no ($P > 0.05$) significant positive correlations between WBSF values and MFL values in each breed (Table 5.5). A relationship between WBSF and MFL is expected because meat tenderness is a function of the collagen content and the myofibrillar structure of muscle (Muir *et al*., 2000; Revilla & Vivar-Quintana, 2006). The correlation between WBSF values and collagen was, however, not determined in the current study. Furthermore, the variation in WBSF values depend more on the myofibrillar content than the total collagen content or

its solubility, especially if it is considered that the shear force on cooked meat may also be a measure of myofibrillar toughness (Sañudo *et al*., 2004). The reason for the absence of significant correlations between WBSF and MFL in this is not clear. The increase in myofibrillar fragmentation is said to be indicative of the amount of tenderization that has taken place in meat (Sañudo *et al.,* 2004*)*. Strydom *et al*. (2000) reported significant within-breed correlations between myofibrillar fragmentation index (MFI) and tenderness in Nguni and Bonsmara steers. In the Nguni there were negative correlations ($P < 0.05$) between WBSF and pH. This is expected since meat with higher pH is normally tender (Silva *et al*., 1999). The relationship between WBSF and pH was, however, not ($P > 0.05$) significant in meat from Bonsmara and Angus steers. The correlation coefficient between WBSF and drip loss was positive and significant ($P < 0.05$) in Nguni, but not in the other two breeds. This implies that meat that loses more water is tougher than meat that loses less water, although it is not clear why such a relationship was not found in meat from the Bonsmara and Angus steers.

In Nguni and Bonsmara steers, meat with high WBSF values after being aged for two days also had high WBSF values after being aged for 21 days. In Angus steers, however, WBSF values for meat aged for two days and the one aged for 21 days were not correlated ($P > 0.05$). The lack of a correlation between WBSF values of Angus steers meat aged for two days and the one aged for 21 days is unexpected, although this is similar to what we reported in our previous study (Muchenje *et al*., 2007). This may be attributed to the less variable WBSF values of meat from the Angus steers (Table 5.3) than those of the WBSF values of meat from the Nguni and Bonsmara steers (Tables 5.1 and 5.2). The lack of correlations between WBSF shear values may also be ascribed to

the fact that aging in Angus steers meat may have been almost complete at two days (Stolowski *et al*., 2006). The respective WBSF values of meat from Angus steers aged for two and 21 days were 42.1 N and 35.9 N (Table 5.3). Beef crosses with more Angus blood were reported to age faster than those crosses with less Angus blood (Stolowski *et al*., 2006).

There was a positive relationship ($P < 0.05$) between drip loss and cooking losses in the Bonsmara, but not in the other two breeds (Table 5.6). Cooking losses are expected to increase with increasing levels of drip loss. The absence of a significant relationship between drip loss and cooking losses may be ascribed to the fact that cooking is largely affected by evaporation losses. In this study evaporation losses accounted for approximately 90 % of the cooking losses. Cooking loss was negatively correlated ($P < 0.05$) to water holding capacity (WHC) in meat from the Bonsmara steers, but not in meat from the other two breeds. There were significant ($P < 0.05$) negative correlations between pH and cooking losses in meat from each of the three breeds except in meat from Nguni and Bonsmara aged for two days. Cooking loss of meat tends to be higher for meat with low WHC (high drip loss, high thawing loss) and low pHu, with no difference between cooking loss of meat with medium or high WHC and pHu (Aaslyng, Bejerholm, Ertbjerg, Bertram, & Andersen, 2003; Razminowicz *et al*., 2006). This agrees with the results in this study, particularly those pertaining to meat from the Bonsmara steers. Meat that is classified as DFD tends to have lower cooking losses (Van der Wal, Bolink, & Merkus, 1988). Cooking losses were also positively correlated ($P < 0.05$) to MFL2 in meat from Nguni steers and to MFL21 in meat from Angus. There was a positive ($P < 0.05$) correlation coefficient between cooking loss for meat aged for two days and meat

aged for 21 days in meat from Bonsmara steers, but not in meat from Nguni and Angus steers. It is not clear why there were no significant correlations between cooking loss for meat aged for two days and meat aged for 21 days in meat from Nguni and Angus steers.

Water holding capacity (WHC) was negatively correlated ($P < 0.05$) to L* and positively correlated ($P < 0.05$) to pH in the Bonsmara steers; only negatively correlated to L* ($P < 0.001$) in Nguni steers and not significantly ($P > 0.05$) correlated to any meat quality trait in the Angus steers (Table 5.7). The presence of a correlation between WHC and L* while there was an absence between WHC and pH in the Nguni confirms the absence of a correlation between L* and pH in the Nguni in the current study. Zhang *et al.* (2005) reported a positive relationship between pH and WHC in beef. There were no ($P > 0.05$) significant correlations between drip loss and WHC within all the three breeds. This is unexpected as meat with low WHC is expected to have high levels of drip loss. The absence of correlations between the two implies that it is not reliable to use the levels of one of these meat quality traits to indicate the levels of the other in meat.

There were no correlations ($P > 0.05$) between pHu and L* in the Nguni steers (Table 5.8). However, there were significant ($P < 0.05$) correlations between L* and pH in Bonsmara and Angus steers. Differences in meat colour have been associated with variations in pHu of the muscle (Hector *et al*., 1992), with higher pHu being associated with dark cuts and vice versa. However, Priolo *et al*. (2001) concluded that the evidence on the causes of variation was mixed. The poor correlation between L* and pHu in meat from Nguni steers in this study is not fully understood. There were significant ($P < 0.01$) positive correlations between drip loss and L* in Bonsmara and Angus steers and a significant ($P < 0.01$) negative correlation between drip loss and pH in the Bonsmara

steers. No significant relationships were found between drip loss, and L* and pH in the Nguni steers.

5.4. Conclusions

There were significant correlations among meat tenderness characteristics such as MFL and WBSF values in Nguni and Bonsmara steers. Notably, no correlations were observed between pH and L* in meat from Nguni steers and between WBSF for meat aged for two days and meat aged for 21 days in Angus steers. This implies that correlations among meat quality traits are breed dependent and therefore information on correlations should be used cautiously when applying it across breeds. There is need, however, to establish the relationships among meat quality traits, fatty acid profiles and sensory characteristics of meat from Nguni, Angus and Bonsmara breeds raised under natural grazing.

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CHAPTER 6: Chemical composition, cholesterol levels and fatty acid profiles of *Longissimus thoracis et lumborum* of Nguni, Bonsmara and Angus steers raised on natural pasture in a low input cattle production system

(Submitted to *Journal of Food Composition and Analysis*)

Abstract

The objective of the current study was to compare chemical composition, cholesterol levels and fatty acid profiles of meat from Nguni, Bonsmara and Angus steers raised on natural pasture. Thirty steers each of Bonsmara and Angus and 40 weaners of Nguni were kept at the University of Fort Hare Farm for 12 months till slaughter. The average slaughter weight of the Nguni, Bonsmara and Angus steers were 224, 260 and 238 kg, respectively. Chemical composition, cholesterol and fatty acid profiles were determined. Nguni steers had higher ($P < 0.05$) dry matter, ash and crude protein content than the other two breeds. Most fatty acid profiles were similar ($P > 0.05$) among the three breeds except that Nguni meat had lower ($P < 0.05$) monounsaturated fatty acid content than meat from the other two breeds. Meat from Angus steers had the lowest ($P < 0.05$) Omega 6 (n-6) to Omega 3 (n-3) ratio. There were significant correlations ($P < 0.05$) among the fatty acids. Meat from Nguni, therefore, compared favourably with that from established breeds in terms of chemical composition, cholesterol levels and fatty acid composition, when raised on natural pasture.

Keywords: Conjugate Linoleic Acid, low density lipoproteins, n-6/n-3 ratio, polyunsaturated fatty acids, Saturated fatty acids

6.1. Introduction

Red meat, such as beef, has a bad reputation in terms of healthy human diet (Aharoni *et al*., 1995; Padre *et al*., 2006). Beef fat is a significant source of saturated fatty acids in the human diet because red meat has a relatively high ratio of saturated to unsaturated fatty acids in its lipids, which is a risk factor for the development of vascular and coronary diseases (Mills *et al*., 1992; Barton *et al*., 2007). The adverse effect of saturated fatty acids on the human plasma cholesterol levels makes it imperative to identify breeds with a relatively higher proportion of unsaturated fatty acid content. The health risk factor of animal-derived lipids has often been overemphasized, although it is evident that these lipids provide physiologically functional and potentially health-beneficial fatty acids (Razminowicz *et al*., 2006). Fatty acid profiles affect sensory attributes of meat such flavour and juiciness (Elmore, Mottram, Enser, & Wood, 1999; Enser, 2001).

The majority of the available reports on beef quality in Southern Africa are based on European beef breeds, such as the Angus and the Hereford on feedlots under commercial farming conditions while most of them have not reported on fatty acid profiles (Strydom *et al*., 2000; 2001). In most communal areas, where most the Nguni and non-descript cattle are found, grazing is communal. In communal grazing, cattle from different households are brought together and graze in areas which are owned by communities with limited and inadequate natural pature management principles being applied, resulting in overgrazing and loss of weight, specially during the dry season (Bester *et al*., 2001; Muchenje *et al*., 2007). This may affect fatty acid composition, since fatty acid composition is closely related to the fatness level (Zembayashi *et al*., 1995; Barton *et al*.,

2007). However, grass-based beef production systems, as practised in communal areas, are low-input systems that are particularly suitable to meet the demand of meat retailers and consumers for naturally animal-friendly produced beef (Razminowicz *et al*., 2006).

Therefore, there is need to assess fatty acid profiles of indigenous cattle breeds in communal areas, such as the Nguni cattle breed in the communal areas of the Eastern Cape of South Africa. No information is available on chemical composition, cholesterol levels and fatty acid profiles of Nguni cattle raised on natural pasture in communal areas in the sweetveld. The objective of the current study was, therefore, to compare chemical composition, cholesterol levels and fatty acid profiles of Nguni, Bonsmara and Angus steers raised on natural pasture.

6.2. Materials and Methods

6.2.1. Animal management, handling and slaughter procedure

Thirty weaners of each of Bonsmara and Angus breed, and 40 weaners of Nguni breed of similar age (around 205 days) were raised at Honeydale Farm, University of Fort Hare till slaughter at 18 months of age. The details the site where the study was conducted and how the animals were managed were as described by Muchenje *et al*. (2007). The average slaughter weight of the Nguni, Bonsmara and Angus steers were 224, 260 and 238 kg, respectively. The average daily gains were 201, 231 and 189 g/day for Nguni, Bonsmara and Angus, respectively. Animal slaughter and dressing was done following usual commercial procedures at the East London Abattoir.

Carcasses were split, weighed and then chilled at 0 - 3^{o}C before being processed the following day after slaughter. The m. *longissimus thoracis et lumborum* (LTL) of the right side was sampled, a day after slaughter, from the 10th rib in the direction of the rump and a 100 mm thick piece of the posterior side of the right LTL was taken for chemical composition, cholesterol and fatty acid profile analyses.

6.2.2. Proximate analyses of meat

A 50 g sample of the LTL was ground and freeze dried for the determination of protein, fat, moisture and ash contents, as described by Association of Official Analytical Chemists (AOAC) (1985).

6.2.3. Cholesterol determination

The extraction and quantification of cholesterol were carried out by the method of Al-Hasani, Hlavac and Carpenter (1993), with modifications (Rowe, Macedo, Visentainer, Souza, & Matsushita, 1999). Meat samples weighing 5-10 g were placed in a 250 ml flat-bottom flask and dispersed in an ethanol-methanol-isopropanol (90: 5: 5 v/v/v) solution in an amount equivalent to 4 ml/g of sample. A 1 ml sample of 60 % KOH was then added. The flask containing this mixture was connected to a water-cooled condenser and refluxed for 1 hour. After cooling to room temperature, 100 ml of hexane was added and the mixture was stirred for 10 minutes and finally 25 ml of deionised

water was added and the mixture was stirred for a further 15 minutes. Layers were then separated and the hexane layer was collected in a flask. An aliquot of 25 ml of the hexane layer was evaporated to dryness under nitrogen. The residue was dissolved in 2 ml of hexane containing 0.2 mg of 5 a-cholestane internal standard/ml and transferred to a vial. Approximately 3 µl were injected into a gas chromatograph. A Shimadzu 14A instrument GC (Japan) fitted with a flame ionization detector (FID, 300 ^{o}C) and a split/splitless injector (260 ^{o}C, split 1: 150) was used for the analysis of cholesterol. Separation was carried out in a fused silica capillary column at 300 ^{o}C (25 m x 0.25 mm), coated with SE-30 (0.25 µm phase thickness) (Quadrex, U.S.A). The carrier gas was hydrogen (1.5 ml/min) and the make-up gas was nitrogen (25 ml/min). Cholesterol identification was made by comparing the relative retention time of peaks from samples with standards from SIGMA (U.S.A.). For peak integration a CG 300 computing integrator (CG Instruments, Brazil) was used.

6.2.4. Fatty acid profile determination

6.2.4.1. Lipid extraction

Total lipid from muscle sample was quantitatively extracted, according to the method of Folch, Lees and Sloane-Stanley (1957), using chloroform and methanol in a ratio of 2:1. An antioxidant, butylated hydroxytoluene was added at a concentration of 0.001 % to the chloroform:methanol mixture. A rotary evaporator was used to dry the fat extracts under vacuum and the extracts were dried overnight in a vacuum oven at 50°C,

using phosphorus pentoxide as moisture adsorbent. Total extractable intramuscular fat (marbling) was determined gravimetrically from the extracted fat and expressed as %fat (w/w) per 100 g tissue. The extracted fat was stored in a polytop (glass vial, with push-in top) under a blanket of nitrogen and frozen at –20°C, pending analyses.

6.2.4.2. Fatty acid analyses

Approximately 10 mg of total lipid (from Folch extraction) was transferred into a Teflon-lined screw-top test tube by means of a disposable glass pasteur pipette. Fatty acid methyl esters (FAME) were prepared for gas chromatography by methylation of the extracted fat, using methanol–BF_3 (Slover & Lanza, 1979; Hur, Ye, Lee, Ha., Park, & Joo, 2004; Diaz *et al*., 2005). Fatty acid methyl esters were quantified using a Varian GX 3400 flame ionization GC, with a fused silica capillary column, Chrompack CPSIL 88 (100 m length, 0.25 μm ID, 0.2 μm film thickness). Column temperature was 40–230°C (hold 2 minutes; 4°C/minute; hold 10 minutes). Fatty acid methyl esters in hexane (1μl) were injected into the column using a Varian 8200 CX Autosampler with a split ratio of 100:1. The injection port and detector were both maintained at 250°C. Hydrogen, at 45 psi, functioned as the carrier gas, while nitrogen was employed as the makeup gas. Varian Star Chromatography Software recorded the chromatograms.

Fatty acid methyl ester samples were identified by comparing the relative retention times of FAME peaks from samples with those of standards obtained from SIGMA (189-19). Conjugated linoleic acid (CLA) standards were obtained from

Matreya, Inc. Fatty acids were expressed as the proportion of each individual fatty acid to the total of all fatty acids present in the sample. The following fatty acid combinations and ratios were calculated: total saturated fatty acids (SFA), total mono-unsaturated fatty acids (MUFA), PUFA, PUFA/SFA ratio (P/S) and n-6/n-3 ratio.

6.2.5. Statistical analyses

The effect of breed on proximate analyses, cholesterol levels and fatty acid profiles was analyzed using GLM procedures of SAS (2000). The significance differences between least-square group means were compared using the PDIFF procedure of SAS (2000). Pearson's correlation coefficients between intramuscular fat (IMF) and CLA, SFA MUFA, PUFA, n-6, n-3, P/S ratio, n-6/n-3 ratio and individual fatty acid were also determined (SAS, 2000).

6.3. Results and discussion

6.3.1. Chemical composition and cholesterol levels

The present study highlights the low fat and cholesterol content of a LTL beef from cattle raised on natural pasture systems. The chemical composition of meat differed ($P < 0.05$) among the three breeds (Table 6.1) with the Nguni steers LTL having higher

Table 6.1

Chemical composition and cholesterol concentrations (and standard errors) of *Longissimus thoracis et lumborum* muscle of Nguni, Bonsmara and Angus steers

	Breed		
	Nguni	Bonsmara	Angus
N	34	29	14
Moisture (%)	77.4 (0.13) [a]	77.7 (0.09) [b]	77.7 (0.13) [b]
Ash (%)	1.07 (0.005) [a]	1.06 (0.005) [b]	1.06 (0.007) [b]
Protein content (%)	21.7 (0.10) [a]	20.8 (0.09) [b]	20.4 (0.21) [c]
Fat content (%)	1.14 (0.079)	1.05 (0.082)	1.24 (0.097)
Cholesterol (mg/100g)	41.5 (1.43)	36.3 (1.32)	40.5 (2.96)

[a,b,c]Means in the same row with different superscripts differ significantly at $P < 0.05$

($P < 0.05$) dry matter, crude protein and ash than the LTL of the other two breeds. The Angus steers LTL had the least ($P < 0.05$) protein content. Intramuscular fat (IMF) was similar among the three breeds, which agrees with Strydom *et al*. (2001), but lower than the fat content reported in Limousin and Charolais young bulls (Revilla & Vivar-Quintana, 2006).

Cholesterol levels among the three breeds were similar ($P > 0.05$). Rule, Macneil, and Short (1997) emphasized that breed, nutrition, and sex do not affect the cholesterol concentration of bovine skeletal muscle. These authors suggested that differences in muscle cholesterol concentration would probably be associated with marked changes in the structure of the muscle cells. Thus, altering cholesterol concentration in muscle may require a marked redistribution of membrane fatty acids (Rule *et al*., 1997). The cholesterol concentrations in this study were lower than those found by Bohac and Rhee (1998) for beef and pork, VanKoevering, Gill, Owens, Dolezal and Strasia (1995) for beef and by Ruiz *et al*. (2005) for *Bos indicus* bulls in Brazil.

The present study also highlights the low cholesterol concentration of a common serving of beef from pasture-based production systems (Padre *et al*., 2006). The consumption of 200 g LTL analyzed in the present study represents a cholesterol intake of 83, 73 and 81 mg from meat from Nguni, Bonsmara and Angus respectively, which corresponds to less than 30 % of the recommended maximum daily cholesterol intake (300 mg/day, Greene & Feldman, 1991; Jiménez-Colmenero, Carballo, & Cofrades, 2001). Costa, Restle and Brondani (2002) and Alfaia *et al*. (2006) observed cholesterol content in beef depends on IMF content. Meat with high levels of IMF has high levels of cholesterol content. Furthermore, plasma cholesterol levels are influenced by the fatty

acid composition of the diet (Flynn, Naumann, Nolph, Krause, & Ellersieck, 1985), with high levels of some long-chain SFA's such as lauric (C12:0), myristic (C14:0) and palmitic acid (C16:0) increasing serum cholesterol levels (Grundy & Denke, 1990; Rowe *et al*., 1999).

6.3.2. Fatty acid profiles

The predominant fatty acids were oleic, palmitic and stearic acids (Table 6.2). There were no ($P > 0.05$) breed effects on levels of most fatty acids (Table 6.2). There were significant breed effects on heptadeconoic acid (C17:1c10), oleic acid (C18:1c9), linoleic acid (LA; C18:2c9,12 (n-6)); conjugated linoleic acid (CLA; C18:2c9t11 (n-6)); arachidic acid (AA; C20:0); MUFA and the n-6/n-3 ratio. The Angus had the highest ($P < 0.05$) CLA, AA, oleic acid, MUFA content and lowest ($P < 0.05$) LA and n-6/n-6 ratio. Similar results were reported by Barton, *et al*. (2007) in Limousin and Charolais heifers that were fed extruded linseed and by Razminowicz *et al*. (2006) in steers from grass-based production systems. The differences in fatty acid composition may be due to different activities of enzymes involved in fatty acid synthesis and modification.

The absence of breed effects on most fatty acid profiles in the current study can be ascribed to the fact the steers were on the same production system. However, the current study contradicts what has been reported by several authors. Breed differences were reported in fatty acid proportions subcutaneous and intramuscular fat of Aberdeen Angus and Wagyu steers by May, Sturdivant, Lunt, Miller and Smith (1993), in muscle phospholipids of Jersey and Limousin cattle by Malau-Aduli, Siebert, Bottema and

Table 6.2

Fatty acid profile (as percentage of the total fatty acids identified) (standard errors) of the *Longissimus thoracis et lumborum* muscle of Nguni, Bonsmara and Angus steers

Fatty acid	Breed		
	Nguni	Bonsmara	Angus
N	15	14	10
C14:0	1.73 (0.156)	1.78 (0.162)	1.67 (0.191)
C14:1c9	0.16 (0.048)	0.19 (0.050)	0.28(0.059)
C15:0	0.44 (0.047)	0.37 (0.049)	0.41(0.058)
C15:1c10	0.22 (0.033)	0.27 (0.035)	0.23(0.041)
C16:0	21.84 (0.616)	21.90 (0.637)	22.18 (0.754)
C16:1c9	2.29 (0.141)	2.09 (0.146)	2.29 (0.173)
C17:0	1.04 (0.047)	1.04 (0.049)	1.03 (0.058)
C17:1c10	0.36 (0.037)[a]	0.47 (0.039)[b]	0.39 (0.046)[ab]
C18:0	17.95 (0.544)	17.96 (0.563)	18.46 (0.667)
C18:1t9	1.44 (0.216)	1.40 (0.224)	1.85 (0.265)
C18:1c9	28.58 (0.738)[a]	29.04 (0.764)[a]	31.50 (0.904)[b]
C18:2c9,12 (n-6) (LA)	8.37 (0.602)[b]	8.51 (0.623)[b]	6.34 (0.737)[a]
C18:2c9t11 (n-6) (CLA)	0.30 (0.047)[a]	0.28 (0.048)[a]	0.39 (0.057)[b]
C20:0 (AA)	0.27 (0.034)[b]	0.17 (0.035)[a]	0.29 (0.042)[b]
C18:3c9,12,15 (n-3)	2.20 (0.155)	2.34 (0.161)	1.85 (0.190)
C22:0	0.43 (0.061)	0.40 (0.063)	0.46 (0.075)
C20:3c11,14,17 (n-3)	0.91 (0.084)	0.77 (0.087)	0.75 (0.103)
C20:4c5,8,11,14 (n-6)	5.68 (0.475)	5.50 (0.491)	4.42 (0.582)
C22:2c13,16 (n-6)	0.28 (0.040)	0.28 (0.042)	0.22 (0.050)
C20:5c5,8,11,14,17 (n-3) (EPA)	2.14 (0.193)	1.96 (0.200)	1.96 (0.237)
C22:5c7,10,13,16,19 (n-3) (DPA)	2.99 (0.240)	3.10 (0.249)	2.78 (0.294)
C22:6c4,7,10,13,16,19 (n-3) (DHA)	0.21 (0.044)	0.10 (0.045)	0.11 (0.054)
PUFA[1]	23.09 (1.647)	22.84 (1.694)	18.79 (2.004)
MUFA[2]	33.05 (0.837)[a]	33.47 (0.867)[a]	36.54 (1.025)[b]
SFA[3]	43.70 (1.128)	43.62 (1.177)	44.49 (1.382)
n-6[4]	14.64 (1.024)	14.57 (1.060)	11.36 (1.254)
n-3[5]	8.46 (0.64)	8.27 (0.661)	7.43 (0.782)
PUFA:SFA[6]	0.55 (0.049)	0.54 (0.051)	0.44 (0.060)
n-6/n-3[7]	1.75 (0.049)[b]	1.79 (0.051)[b]	1.53 (0.060)[a]

[a,b]Means in the same row with different superscripts differ significantly at $P < 0.05$

[1]Polyunsaturated fatty acids. [2]Monounsaturated fatty acids. [3]Saturated fatty acids. [4]Omega-6 fatty acids. [5]Omega-3 fatty acids. [6]Ratio of polyunsaturated fatty acids and saturated fatty acids. [7]Ratio of n-6 and n-3 fatty acids. AA, arachidonic acid; LA, linolenic acid; CLA, conjugated linoleic acid; DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid

Pitchford (1998) in muscle neutral lipids and phospholipids of Holstein Friesian and Welsh Black steers (Choi *et al*., 2000; Vatansever *et al*., 2000), and in total lipids of muscle of Simmental and Red Angus steers by Laborde, Mandell, Tosh, Wilton and Buchanan-Smith (2001). Breed differences reflect underlying differences in gene expression or activities of enzymes involved in fatty acid synthesis, desaturation or chain elongation, and thus deserve further attention (Barton, *et al*., 2007). However, Baublits *et al*. (2006) reported no differences between biological types for fatty acid profiles. Huerta-Leidenz, Cross, Savell, Lunt, Baker and Smith (1996) reported that interpretation of the literature on fatty acids is difficult because of the inevitable confounding of age, live weight, fatness, plane of nutrition, developmental traits, and other factors that affect lipid metabolism.

The observed n-6/n-3 ratios (1.75 in Nguni, 1.79 in Bonsmara and 1.53 in Angus) were within the recommended levels of 4:1 (Padre *et al*., 2006; Razminowicz *et al*., 2006). These levels are considerably lower than those reported by Raes *et al*., (2003) for animals fattened under highly intensive production conditions (5–7) and for animals from extensive production systems (2.5–3), and by Cuvelier *et al*. (2006) in intensively fattened Belgian Blue, Limousin and Angus bulls (3.4-6.4). The low n-6/n-3 levels in the current study are desirable for meat consumers' healthy reasons. The n-6 and n-3 fatty acids have important roles in reducing the risk of coronary heart disease; however, the optimal balance between these two classes of fatty acids is still a matter of debate (Hu, 2001). The PUFA from the n-6 series are involved in the synthesis of eicosanoids biologically active in very small quantities and with properties much more inflammatory than eicosanoids from the n-3 series (Simopoulos, 2002). Therefore, nutritional

guidelines recommend reductions in the intake of fat, especially SFA, and to optimise the intake of n-6 fatty acids relative to n-3 fatty acids (Cuvelier *et al*., 2006). The low ratio of n-6/n-3 PUFA observed in this study could be due to the fact that the steers relied on grass which contains high levels of 18:3 (Wood *et al*., 2003).

The PUFA/SFA ratios in the current study ranged from 0.44 in meat from Angus steers to 0.55 in meat from Nguni steers. These were considerably higher than those reported by Ruiz *et al*. (2005) in bulls (0.25) in comparison to steers (0.16) under grass-based production systems. Cuvelier *et al*. (2006) reported PUFA/SFA ratios of 0.80, 0.29 and 0.21 for intensively fattened Belgian Blue, Limousin and Aberdeen Angus, respectively. A higher content of PUFA and lower amounts of both MUFA and SFA is desirable (Hoffman & Wiklund, 2006). The ratio between PUFA and SFA ratios for Nguni (0.55) and Bonsmara (0.54) steers were above the optimal value of 0.45 (Wood & Enser, 1997), while that of the Angus (044) were just below the optimal value. The differences in the observed PUFA/SFA ratios to those reported by other authors could be due to differences in feeding systems (Wood & Enser, 1997), breeds and age of the animals. Changes due to lipogenesis, desaturation, hydrogenation of forage PUFA to SFA by rumen bacteria (Wood & Enser, 1997; Girolami, Marsico, D'Andrea, Braghieri, Napolitano, & Cifuni, 2003) and lypolysis (Ruiz *et al*., 2005) also causes variations in PUFA/SFA ratios. Furthermore, while information is widely available on the fatty acid composition of the intramuscular fat in most beef breeds (Engle & Spears, 2004; Itoh, Johnson, Cosgrove, Muir, & Purchas, 1999; Raes *et al*., 2003) comparison of the data is difficult because of differences in the experimental designs.

Beef from Angus steers had the highest ($P < 0.05$) CLA (C18:2c9t11) levels among the three breeds. The reason for the breed differences is not clear. However, the CLA levels in this study were similar to those reported by Razminowicz *et al*. (2006) under grass-based beef production systems. Although scientific evidence for beneficial health effects of CLA's in humans is variable and still unconvincing (Razminowicz *et al*., 2006), *cis*-9, *trans*-11 18:2 (18:2*c*9*t*11), was the predominant isomer naturally occurring in this study and is particularly believed to be beneficial for human health (Kramer *et al*., 1997). The 18:2*c*9*t*11 is mainly a product of endogenous desaturation of *trans*-vaccenic acid (18:1*t*11), which is the predominant 18:1-*trans* isomer in grass-fed cattle (Dannenberger *et al*., 2004). Chin *et al*. (1992) argued that the best dietary sources of CLA are foods produced by grass-fed ruminants. Dannenberger *et al.* (2004) found 1.15 and 2.54mg of 18:2*c*9*t*11/100 g fresh muscle tissue of concentrate- and grass-fed bulls, respectively. In the present study, the respective levels of CLA for Nguni, Bonsmara and Angus were 3.0, 2.8 and 3.9 mg of 18:2*c*9*t*11/100 g fresh muscle tissue.

In the MUFA class, C18:1cis fatty acids presented the highest value, with the Angus steers having the highest ($P < 0.05$) value of C18:1cis fatty acids. Varela *et al*. (2004) and Noci, Kiely, Monahan, Stanton and Moloney (2005) also reported C18:1cis as the predominant fatty acid. The C18:1cis fatty acids reduce human LDL-cholesterol and increases HDL-cholesterol concentrations in blood (Katan, Zock, & Mensink, 1994), which result in lower risk of coronary problems. Studies have demonstrated a strong relationship between LDL-cholesterol levels and human cardiovascular diseases and that HDL-cholesterol has an inverse relation with the risk of cardiovascular diseases (Kwiterovich, 1997).

In the PUFA, 18:2 n-6 and 20:4 n-6 predominated in LTL of all animals studied, besides the presence of long chain fatty acids resulting from the elongation of acids 18:2 n-6 and 18:3 n-3. The 20:4 n-6 has been noted to have cholesterol-lowering attributes *in vitro* (Viljoen, 1999). The SFA varied from 14 to 22 carbon atoms, with 16:0 and 18:0 dominating in this class. Noci *et al*. (2005) also reported the C16:0 as the dominant SFA. C16:0, C18:0 and C18:1 have also been reported to be the most abundant fatty acids in lamb (Enser, Hallett, Hewitt, Fursey, & Wood, 1996; Rowe *et al*., 1999), beef and pork (Enser *et al*., 1996). According to Rowe *et al*. (1999), myristic (C14:0) and C16:0 acid raise both low-density (LDL) and high-density (HDL) serum cholesterol, although C18:0 has little effect. Therefore, the high levels of C16:0 in the current study are not desirable, although this is countered by relatively high levels of PUFA.

6.3.3. Correlations between intramuscular fat and fatty acids

There were correlations ($P < 0.05$) between intramuscular fat levels and most fatty acid levels in all the three breeds (Table 6.3). No correlations ($P > 0.05$) were, however, found between intramuscular fat levels and C18:1t9; C20:0 and the n-6/n-3 ratio in all the three breeds. Increasing levels of IMF were associated ($P < 0.05$) with lower concentrations of C18:2n-6 and C18:3n-3 in triacylglycerol, and with lower concentrations of most PUFA in phospholipids from all breeds. These findings agree with Itoh *et al*. (1999). Kazala, Lozeman, Mir, Laroche, Bailey and Weselake (1999) hypothesized that the negative association between C18:2n-6 and total lipid content may be due to a dilution of membrane phospholipids with increasing triacylglycerols. Padre *et*

Table 6.3

Linear relationship (r) between intramuscular fat (IMF) content and the fatty acid composition of the *Longissimus thoracis et lumborum* muscle of Nguni, Bonsmara and Angus steers.

Fatty acid	r (Nguni)	r (Bonsmara)	r (Angus)
C14:0	0.95 (***)	0.84 (***)	0.85 (***)
C14:1c9	0.87 (***)	0.17 (NS)	0.13 (NS)
C15:0	0.64 (**)	0.28 (NS)	0.26 (NS)
C15:1c10	-0.60 (*)	-0.83 (***)	-0.82 (**)
C16:0	0.89 (***)	0.84 (***)	0.76 (*)
C16:1c9	0.81 (***)	0.37 (NS)	0.74 (*)
C17:0	0.60 (*)	0.68 (**)	0.35 (NS)
C17:1c10	-0.68 (**)	-0.16 (NS)	-0.23 (NS)
C18:0	0.34 (NS)	0.66 (**)	0.06 (NS)
C18:1t9	0.04 (NS)	-0.10 (NS)	0.11 (NS)
C18:1c9	0.82 (***)	0.53 (NS)	0.72 (*)
C18:2c9,12 (n-6)	-0.84 (***)	-0.70 (**)	-0.92 (***)
C18:2c9t11 (n-6)	0.62 (*)	0.56 (*)	0.81 (**)
C20:0	0.09 (NS)	0.11 (NS)	-0.18 (NS)
C18:3c9,12,15 (n-3)	-0.89 (***)	-0.75 (**)	-0.87 (***)
C22:0	-0.85 (***)	-0.57 (*)	-0.45 (NS)
C20:3c11,14,17 (n-3)	-0.80 (***)	-0.62 (*)	-0.55 (NS)
C20:4c5,8,11,14 (n-6)	-0.91 (***)	-0.90 (***)	-0.79 (**)
C22:2c13,16 (n-6)	-0.44 (NS)	-0.48 (NS)	-0.57 (NS)
C20:5c5,8,11,14,17 (n-3)	-0.85 (***)	-0.82 (***)	-0.89 (***)
C22:5c7,10,13,16,19 (n-3)	-0.93 (***)	-0.88 (***)	-0.87 (***)
C22:6c4,7,10,13,16,19 (n-3)	-0.54 (*)	-0.37 (NS)	-0.37 (NS)
PUFA[1]	-0.91 (***)	-0.90 (***)	-0.88 (***)
MUFA[2]	0.80 (***)	0.53 (NS)	0.81 (**)
SFA[3]	0.78 (***)	0.90 (***)	0.56 (NS)
n-6[4]	-0.91 (***)	-0.82 (***)	-0.85 (**)
n-3[5]	-0.90 (***)	-0.94 (***)	-0.90 (***)
PUFA:SFA[6]	-0.88 (***)	-0.88 (***)	-0.81 (**)
n-6/n-3[7]	0.26 (NS)	0.45 (NS)	0.16 (NS)

[1]Polyunsaturated fatty acids. [2]Monounsaturated fatty acids. [3]Saturated fatty acids. [4]Omega-6 fatty acids. [5]Omega-3 fatty acids. [6]Ratio of polyunsaturated fatty acids and saturated fatty acids. [7]Ratio of n-6 and n-3 fatty acids.

al. (2006) reported breed differences in lipid content in tissue of cattle, which was indirectly related to conjugated linoleic acid (CLA) content.

Higher IMF content in the Nguni and Bonsmara steers was also associated with a higher ($P < 0.05$) SFA content, while higher IMF was also associated with a higher ($P < 0.05$) MUFA content in Nguni and Angus steers, whereas the PUFA content was negatively correlated ($P < 0.05$) to IMF in all the three breeds. In the present study, the SFA's C14:0, C16:0 and C18:0 (only in Bonsmara), as well as the MUFA's C16:1 and C18:1 ($P < 0.01$) with an increase ($P < 0.05$) in the IMF content of the LTL muscle. These observations could be mainly due to the preferential incorporation of PUFA into the phospholipids associated within the cell membranes, whereas SFA and MUFA are deposited mainly in the triacylglycerol fraction, which increases with IMF content (Raes *et al*., 2003, Wood *et al*., 2003, De Smet, Raes, & Demeyer, 2004). The increase in PUFA content in the steers was associated with higher total n-3 fatty acid content and higher total n-6 content.

6.4. Conclusions

Except for MUFA, N-6/n-3 and some few fatty acids, there were no breed effects on most fatty acids, IMF and cholesterol levels. The Angus had the highest MUFA content and lowest n-6/n-3 ratio. There were correlations between intramuscular fat and most fatty acids in all breeds. It can be concluded that, under adverse conditions, which are common during the dry season in the rural areas of the Eastern Cape, most Nguni meat fatty acids were similar to that of Angus and Bonsmara, although the Angus meat

had the highest MUFA content and lowest n-6/n-3 ratio. Therefore, besides being a smaller breed the Nguni can compete favourably with established breeds in terms of chemical composition, cholesterol levels and fatty acid composition. The present study highlights the low fat content of beef from cattle raised natural pasture systems. Since fatty acids may cause changes in sensory evaluations there is still a need to perform a sensory evaluation of the Nguni cattle meat against the established beef breeds.

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Chapter 7: Sensory evaluation of meat from Nguni, Bonsmara and Angus steers raised on natural pasture in the Eastern Cape, South Africa

(Submitted to *Animal*)

Abstract

The objective of the current study was to compare sensory characteristics of meat from 19-month old Nguni, Bonsmara and Angus steers raised on natural pasture. At slaughter, carcasses were electrically stimulated. The *m. longissimus thoracis et lumborum* was sampled for the evaluation of meat sensory characteristics. Meat from Nguni steers had the best ($P < 0.05$) scores in most sensory characteristics, with more than 50 % of the characteristics having scores above 5.5 on a scale of 1-8. Meat from Angus steers had the lowest ($P < 0.05$) sensory scores in most characteristics, with more than 60 % of the characteristics having scores less than 5.3. There were no breed effects ($P > 0.05$) on flavour intensity and sustained juiciness of meat aged for 2 days. Sensory characteristics of meat from Nguni were better than those of meat from Bonsmara and Angus, when raised on natural pasture.

Keywords: Acceptability, aroma, flavour; juiciness, tenderness

7.1. Introduction

Promotion of beef production in communal areas from indigenous and adaptable cattle breeds, such as the Nguni, has got the potential to increase off-take and reduce beef imports in South Africa where local meat supply cannot meet the demand for meat products. Assessment of meat production in the communal areas should include meat acceptability. Our previous study focused on growth performance, carcass characteristics

and meat quality (Muchenje *et al*., 2007a), but did not include sensory evaluation. Components of the palatability of meat include tenderness, juiciness and flavour. Aroma, the impression that you form on the first bite of meat and the amount of connective tissue in meat are also important sensory characteristics (Hoffman, Kroucamp, & Manley, 2007). Of these attributes, consumers consider tenderness to be the most important factor influencing meat quality (Strydom *et al*., 2000).

Although Nguni meat had the lowest lightness (L* value), the highest protein content and highest dry mater content (Muchenje *et al*., 2007a), the other histological, physical and chemical characteristics were similar to those of the Bonsmara and Angus. It is not clear whether the observed differences in the L* value among the breeds, though of little practical value (Muchenje *et al*., 2007a), could be reflected in the sensory testing of the meat. There is, therefore, need to evaluate the palatability and acceptability of the meat among the consumers. Studies on sensory characteristics of Nguni meat have been on feedlot systems under commercial farming conditions (Strydom *et al*., 2000; 2001). No information is available on the sensory characteristics of meat from Nguni cattle raised on natural pasture without dietary supplementation, as is practised in rural areas. There is need to evaluate sensory characteristics of meat from the Nguni cattle produced under conditions that mimic rural conditions and management systems.

Therefore, the objective of the current study was to compare sensory characteristics of meat from Nguni versus that meat from Bonsmara and Angus steers when raised on natural pasture. The hypothesis tested was that, under natural grazing, sensory characteristics of meat from Nguni steers are similar to sensory characteristics of meat from the Bonsmara and Angus breeds.

7.2. Materials and Methods

7.2.1 Animal management, handling and slaughter procedure

Thirty weaners of each of Bonsmara and Angus breed, and 40 weaners of Nguni breed of similar age (around 205 days) were raised at Honeydale Farm, University of Fort Hare till slaughter at 18 months of age. Details on the site and animal management were as described by Muchenje *et al*. (2007a). The average slaughter weight of the Nguni, Bonsmara and Angus steers were 224, 260 and 238 kg, respectively. The average daily gains were 201, 231 and 189 g/day for Nguni, Bonsmara and Angus, respectively. Animal slaughter and dressing was done following usual commercial procedures at the East London Abattoir.

The m. *longissimus thoracis et lumborum* (LTL) of the left and right sides were sampled, a day after slaughter, from the 10^{th} rib in the direction of the rump in the following order and amounts for sensory characteristics of meat analyses:

a) 300 mm thick of the anterior side of the left LTL for 2 day aged sensory test, and

b) 300 mm thick of the anterior side of the right LTL for 21 days aged sensory test,

This amounted to approximately 1.5 kg meat sample per animal.

7.2.2. Sensory evaluation

For sensory analyses, steaks were thawed in their vacuum bags in tap water for four hours before each session to an internal temperature of 17–19 °C. Meat was cooked in a double plate grill (SAMMIC P8D-2. Azpeitia, Spain) at 200 °C, until it reached 70 °C internal temperature, which was monitored by an internal thermocouple (JENWAY 2000, Dunmow, England). Every steak was then trimmed of any external connective tissue, cut into approximately 2x2x2 cm samples, wrapped in coded aluminium foil and stored in warm pans at 60 °C until tasting. Samples were put in plates and allocated in individual booths under red lighting to mask differences in meat colour. Each of the 10 panellists had wide experience in meat sensory evaluation. The panel performed training tests using the methods outlined in ISO 8586-1 (1993). From each plate the panellists evaluated six samples, corresponding to the two ageing times (2 and 21 days) in each of the three breeds. The panellist evaluated all samples once. Samples were presented in a different order to each panellist.

On an eight-point rating scale (Appendix 2), assessments were made on beef aroma intensity, initial impression of juiciness (defined as the amount of fluid exuded on the cut surface when pressed between thumb and forefinger), first bite (defined as the impression that you form on the first bite), sustained impression of juiciness (defined as the impression of juiciness that you form as you start chewing). The assessment criteria also included tenderness (defined as the opposite of the force required to bite through the sample with the molars), amount of connective tissue (defined as the chewiness of the meat), overall flavour intensity (defined as the combination of taste while chewing and

swallowing – referring to the typical beef flavour), and a-typical flavour intensity (this refers to a flavour that is present over and above typical beef flavour, such as livery, bloody, metallic, grassy, cooked vegetables). A score of 1 stood for extremely low aroma and flavour intensities, tough, dry, abundant connective tissue and no a-typical flavour and 8 stood for extremely intense aroma and flavour intensities, very tender, very juicy, no connective tissue and extremely intense a-typical flavour (ISO 8586-1, 1993).

7.2.3. Statistical analysis

Data from the sensory panel tests were analysed by the GLM procedure of SAS (2000) considering the effect of breed, panellist and their interaction. Significance differences between least-square group means were compared using the PDIFF test of SAS (2000), with a significance level of $P < 0.05$.

7.3. Results and discussion

7.3.1. Sensory characteristics of meat

Tables 7.1 and 7.2 show that there were significant ($P < 0.05$) differences among the breeds and among the panellists in most sensory characteristics. This was despite the fact that the Warner-Bratzler shear force (WBSF) values and fat content for the three breeds were similar (Muchenje *et al*., 2007a). There was no breed by panellist interaction

Table 7.1

Effects of breed and panellist on sensory characteristics of meat from Nguni, Bonsmara and Aberdeen Angus steers aged for two days

Meat quality characteristic	Breed	Panellist	Coefficient of Variation (%)
Aroma intensity	**	NS	20
Initial impression of juiciness	**	***	12
First bite	*	***	30
Sustained impression of juiciness	NS	***	16
Muscle fibre & overall tenderness	**	NS	27
Amount of connective tissue	*	***	25
Overall flavour intensity	NS	***	15
A-typical flavour intensity	NS	NS	48

Levels of * $P < 0.05$; **$P < 0.01$; and ***$P < 0.001$. NS = Not significant ($P > 0.05$).

Table 7.2

Effects of breed and panellist on sensory characteristics of meat from Nguni, Bonsmara and Aberdeen Angus steers aged for 21 days

Meat quality characteristic	Aging duration (days)	Breed	Panellist	Coefficient of Variation (%)
Aroma intensity	21	**	NS	24
Initial impression of juiciness	21	**	NS	14
First bite	21	*	***	20
Sustained impression of juiciness	21	**	**	15
Muscle fibre & overall tenderness	21	*	**	16
Amount of connective tissue	21	*	***	16
Overall flavour intensity	21	NS	***	13
A-typical flavour intensity	21	NS	***	39

Levels of * $P < 0.05$; **$P < 0.01$; and ***$P < 0.001$. NS = Not significant ($P > 0.05$).

($P > 0.05$) on most sensory characteristics, indicating that the panellist as a factor would not affect the trends of the scores reported in the current study. There were no differences ($P > 0.05$) among the panellists in the scores for aroma intensity, initial impression of juiciness of meat aged for two days, muscle fibreness and tenderness of meat aged for two days and a-typical flavour for meat aged for two days. There were no breed effects ($P > 0.05$) on flavour intensity, a-typical flavour intensity for meat aged for two and 21 days, and sustained juiciness of meat aged for 2 days.

Tables 7.3 and 7.4 show that meat from Nguni steers had the best ($P < 0.05$) scores in most sensory characteristics, with more than 50 % of the characteristics having scores above 5.5. Meat from Angus steers had the lowest ($P < 0.05$) sensory scores in most characteristics, with more than 60 % of the characteristics having scores less than 5.3. The results in this study are comparable with Strydom *et al*. (2001) in strains of Nguni and Bonsmara that were raised in a feedlot, although the scores in this study were lower than those reported by these authors. While we found breed differences ($P < 0.0$) in aroma in the current study, Strydom *et al*. (2001) did not find differences in aroma among the strains of Nguni and Bonsmara.

However, as in this study, no differences in flavour among the different strains of Nguni and Bonsmara were obtained. The absence of breed differences on flavour agrees with the absence of breed differences on most fatty acids in meat from the steers that were used in this study (Muchenje *et al*., 2007b). Flavour depends on the quantity and composition of fat in the meat (Melton, 1990; Wood & Enser, 1997; Calkins & Hodgen, 2007). Relationships between fat composition and flavour have also been observed for pork (Cameron, Enser, Nute, Whittington, Penman, & Fisken, 2000) and in game meat

Table 7.3

Least square means and standard errors of means (in parenthesis) of sensory characteristics of meat from Nguni, Bonsmara and Aberdeen Angus steers aged for two days

Meat quality characteristic	Breed		
	Nguni	Bonsmara	Angus
Aroma intensity	5.7 (0.07)[a]	5.3 (0.09)[b]	5.7 (0.18)[a]
Initial impression of juiciness	5.6 (0.09)[a]	5.4 (0.05)[b]	5.5 (0.11)[ab]
First bite	4.9 (0.10)[a]	4.6 (0.11)[b]	4.3 (0.23)[b]
Sustained impression of juiciness	5.5 (0.05)	5.4 (0.07)	5.3 (0.14)
Muscle fibre & overall tenderness	5.1 (0.07)[a]	4.9 (0.10)[a]	4.4 (0.21)[b]
Amount of connective tissue	4.9 (0.08)[a]	4.6 (0.10)[b]	4.5 (0.19)[b]
Overall flavour intensity	5.5 (0.05)	5.4 (0.06)	5.5 (0.13)
A-typical flavour intensity	2.1 (0.06)	2.0 (0.08)	1.9 (0.16)

Values in the same row with different superscripts are significantly different at $P < 0.05$.

Table 7.4

Least square means and standard errors of means (in parenthesis) of sensory characteristics of meat from Nguni, Bonsmara and Aberdeen Angus steers aged for 21 days

Meat quality characteristic	Breed		
	Nguni	Bonsmara	Angus
Aroma intensity	5.5 (0.09)[a]	5.1 (0.10)[b]	5.7 (0.20)[a]
Initial impression of juiciness	5.3 (0.05)[a]	5.5 (0.06)[a]	5.1 (0.12)[b]
First bite	5.8 (0.08)[a]	5.7 (0.09)[a]	5.3 (0.18)[b]
Sustained impression of juiciness	5.3 (0.06)[a]	5.6 (0.06)[b]	5.1 (0.13)[a]
Muscle fibre & overall tenderness	5.9 (0.06)[a]	5.8 (0.07)[a]	5.5 (0.15)[b]
Amount of connective tissue	5.6 (0.06)[a]	5.5 (0.07)[a]	5.2 (0.14)[b]
Overall flavour intensity	5.6 (0.05)	5.6 (0.06)	5.5 (0.11)
A-typical flavour intensity	2.1 (0.06)	2.3 (0.07)	2.2 (0.14)

Values in the same row with different superscripts are significantly different at $P < 0.05$.

(Hoffman *et al*., 2007), although flavour is a very complex attribute of meat palatability (Calkins & Hodgen, 2007). Aroma score was similar (P > 0.05) between Nguni and Angus, and better than in Bonsmara.

The similar (P > 0.05) juiciness scores for meat aged for two days between the Nguni and Bonsmara, and the higher (P < 0.05) juiciness scores in meat from Bonsmara aged for 21 days than that from the Nguni in this study contradicts Strydom *et al*. (2001), who reported higher juiciness scores on Nguni strains than on Bonsmara strains. Juiciness scores were lowest (P <0.05) in meat from Angus steers. Since juiciness depends on the quantity and composition of fat in the meat (Melton, 1990; Wood & Enser, 1997), it is not clear why there were breed differences on juiciness yet the three breeds had similar fatty acid composition, although there were some breed differences in the MUFA and n-6/n-3 ratio (Muchenje *et al*., 2007b). The breed differences in the MUFA and n-6/n-3 ratio could possibly explain the differences in juiciness. The MUFA and n-6/n-3 ratio, however, did not affect flavour in this study. Hoffman *et al*. (2007) did not observe any correlation between IMF content and sustained juiciness ratings of the meat. The same authors suggested that the lack of correlation between IMF and sustained juiciness could have been due to the relative low total fat content (<2%) of the springbok meat. This could have been the case in this study where fat IMF content was low (< 1.5 %, Muchenje *et al*., 2007b).

Amount of connective tissue, muscle fibre and overall tenderness and impression on first bite scores were highest (P < 0.05) in meat from Nguni steers and lowest (P < 0.05) in meat from Angus steers. This agrees with Strydom *et al*. (2001) who found Nguni strains to have higher tenderness and residual tissues scores in Nguni strains than

in Bonsmara strains. Hoffman *et al.* (2007) reported an inverse correlation between mean shear force values and tenderness ratings of game meat confirming a decrease in tenderness ratings with an increase in the shear force values of the meat. In our earlier report (Muchenje *et al.*, 2007a), no breed differences were observed on WBSF and myofibrillar fragmentation length (MFL). The finding that Nguni meat had higher scores for amount of connective tissue, muscle fibre and overall tenderness and impression on first bite scores, therefore, contradicts the histological and physical meat characteristics. It is, therefore, highly recommended to use both laboratory and sensory evaluation when assessing meat quality.

Meat that was aged for 21 days had higher amount of connective tissue, muscle fibre and overall tenderness and impression on first bite scores than the meat that was aged for two days. Generally, meat tenderness improves with aging. Unlike with the WBSF values where there were no differences in tenderness between the meat that was aged for two and 21 days in Angus steers (Muchenje *et al.*, 2007a), tenderness as assessed by the panellists had a higher ($P < 0.05$) score (5.5 ± 0.15) for meat aged for 21 days than for meat aged for two days (4.4 ± 0.21). Meat tenderness is a function of the collagen content, heat stability and the myofibrillar structure of muscle and these appear to be affected mainly by the rate of growth of the cattle rather than breed *per se* (Muir *et al.*, 2000; Monson *et al.*, 2005). The myofibrillar component of tenderness can also be influenced by the calpain proteolytic enzyme system during ageing of the carcass post-mortem. Wheeler and Koohmaraie (1991) suggested that the myofibrillar component could be a more important factor than the connective tissue characteristics in influencing meat tenderness. This could be applicable in this study where the animals were

slaughtered at a young age implying that the muscles were likely to be low in connective tissue.

7.4. Conclusions

Meat from Nguni steers had the best sensory characteristics while meat from Angus steers had the lowest sensory scores in most sensory characteristics. It can be concluded that, under adverse conditions, which are common during the dry season in the rural areas of the Eastern Cape, sensory characteristics of meat from the Nguni was the best when compared with Angus and Bonsmara cattle breeds. Therefore, besides being a smaller breed the Nguni produces meat that is preferred by meat consumers.

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CHAPTER 8: General Discussion, Conclusions and Recommendations

8.1. General Discussion

The objective of the current study was compare tickloads, growth performance, response to stress, carcass characteristics and meat quality of Nguni, Bonsmara and Anus steers raised on natural pasture. The study was conducted over a period of two years from April 2005 to end of March 2007. The steers grazed on natural pasture without any supplementation. One group half the steers in each group were dipped once a fortnight and the rest were not dipped. Monthly weights and tick counts were recorded until the steers were slaughtered at 18 months.

In Chapter 3, the effects of dipping and breed on tick loads were determined. The effects of tick loads on productive performance of the steers were also determined. Effects of breed and dipping on meat quality were determined in Chapter 4. Also determined in Chapter 4 were the effects of stress on meat quality parameters, such as pHu, colour, drip loss, WHC and cooking loss. Chapter 5 dealt with the determination of relationships among meat quality traits. Chemical composition of meat, cholesterol levels and fatty acid profiles were determined in Chapter 6. Chapter 7 was on the sensory evaluation of meat from the three breeds.

The dipped Nguni steers had lowest tick counts while the non-dipped Angus steers had the highest tick counts (Chapter 3). However, dipping did not affect growth performance and meat quality. Average daily gain (ADG) was similar among the three

breeds. The Bonsmara steers had the heaviest carcasses while the Nguni and Angus steers were the lightest. The Bonsmara also had the highest dressing percentage while the Nguni had the lowest dressing percentage. The current study has shown that while the non-dipped steers had higher tick loads than the dipped ones, their growth and carcass characteristics were similar. The study has also shown that, despite being a small-framed breed, the Nguni steers had similar ADG to the large-framed Bonsmara and Angus steers. On the basis of adaptability, as shown by tick counts, indigenous breeds, such as the Nguni, are then recommended for the communal areas.

The Bonsmara was the most responsive to stress, although its meat was not the darkest (Chapter 4). Relationships between stress responsiveness and meat quality characteristics were breed dependent. Levels of catecholamines (epinephrine and norepinephrine) were only significantly correlated to L* values in the Nguni steers. This agrees with the theory that when animals are stressed before slaughter they release catecholamines which deplete glycogen with resultant low lactic acid production leading to higher pH and darker meat. However, there was no significant correlation between catecholamine levels and pH in this study. There was also a positive correlation between dopamine and WB2 in the Nguni steers. Positive correlation between dopamine levels and pH, and negative correlations between dopamine in and WB2 and cooking losses in the Bonsmara were obtained. There were no relationships among stress responsiveness hormones and meat quality traits in Angus steers. Relationships between stress responsiveness and meat quality depend on genetic factors and past experiences of the animals, and are normally complex and are difficult to interpret (Grandin, 1997).

The meat quality of the three breeds was similar, except that the Nguni meat was significantly darker than meat from the other breeds (Chapter 4). The cause of the differences between L* values among the breeds was not clear. O'Neill *et al*. (2006) speculated that this could be due the fact that the Nguni cattle release more stress hormones that lead to the depletion of glycogen which ultimately results in a lower glycolytic potential. A lower glycolytic potential results in low lactic acid production thus higher pH in meat. Meat with higher pH tends to be darker. Such a relationship was not observed in this study.

There were within-breed differences in correlations among meat quality characteristics (Chapter 5). The most striking ones were the lack of a significant correlation between L* values and pH, and the lack of correlations between Warner Bratzler shear forces for meat aged for two and 21 days (WBSF2 and WBSF21 respectively) in meat from the Angus steers. According to Purchas *et al*. (1999) and O'Neill *et al*. (2006), meat with high pH would be expected to be darker, but such a relationship was not found in this study. It is generally expected that meat that is tender after being aged for two days would also be expected to be tender after being aged for 21 days, but this was not the case with the Angus steers in this study.

The chemical composition of meat significantly differed among the three breeds with the Nguni steers' LTL having higher dry matter, crude protein and ash than the other two breeds (Chapter 6). The LTL for Angus steers had the least protein content. Except for MUFA, N-6/n-3 and some few fatty acids, there were no breed effects on most fatty acids, IMF and cholesterol levels. The levels of cholesterol in this study were lower than those reported in literature (Bohac & Rhee, 1998; VanKoevering *et al*., 1995; Ruiz *et al*.,

2005). The Angus had the highest MUFA content and lowest n-6/n-3 ratio. There were negative correlations between IMF and PUFA, n-6 and n-3, and positive correlations between IMF and CLA, MUFA and SFA in all breeds. Fatty acid composition is known to affect the flavour and juiciness of meat (Melton, 1990; Wood & Enser, 1997; Calkins & Hodgen, 2007).

The sensory evaluation (Chapter 7) showed that Nguni meat was the most preferred. Meat from Nguni steers had the best scores in most sensory characteristics, with more than 50 % of the characteristics having scores above 5.5. Meat from Angus steers had the lowest sensory scores in most characteristics, with more than 60 % of the characteristics having scores less than 5.3. This contradicted the results from meat quality laboratory analyses and fatty acid profile analyses where no significant differences among breeds in terms of tenderness and fatty acid profiles. The contradiction is difficult to explain. Several reports have shown that juiciness and flavour depend on the quantity and composition of fat in the meat (Melton, 1990; Wood & Enser, 1997; Calkins & Hodgen, 2007), although flavour is a very complex attribute of meat palatability (Calkins & Hodgen, 2007). The negative influence of the intramuscular fat (IMF) content of meat on health aspects, however, competes with its positive influence on meat juiciness and flavour (Issanchou, 1996).

8.2. Conclusions

The Nguni had lowest tick counts while the Angus had the highest tick counts. While dipping significantly reduced ticks on steers, tick loads did not affect liveweight,

carcass and meat quality of the steers. In terms of meat quality, the Nguni is similar to the other two breeds. However relationships among meat quality are breed-dependent. While the Nguni meat was darker than that of the other two breeds, L* was not related to pH nor stress responsiveness hormones. Relationships between stress responsiveness and meat quality traits were breed-dependent. Although there were higher levels of MUFA and lower n-6/n-3 ratio in meat from Angus steers, there were no differences among the three breeds in terms of fatty acid profiles. Cholesterol levels did not differ among the three breeds and were lower than levels reported in literature. The sensory evaluation showed that the Nguni meat was the most preferred. It can be concluded that, in addition, to being adapted to harsh conditions that characterise most communal areas, the Nguni has similar meat quality as the large framed Bonsmara and Angus, and has the most preferred meat in terms of sensory evaluation. The Nguni, therefore, has a potential in organic meat production

8.3. Recommendations

It can be recommended that natural pasture based cattle production systems should use the adapted breed, the Nguni. The use of the Bonsmara is also recommended. Information on relationships among stress responsiveness and meat quality should be used with caution. Higher preference of Nguni meat from the sensory evaluation indicates that Nguni cattle production has a potential.

Areas that require further research include:

►Effect of handling animals at farms, transportation and the pre-slaughter environment on meat quality. The studies should focus on the relationships between stress hormone levels at farms, at arrival and just before slaughter, and their relationships with glycogen depletion, glycolytic potential, glycolysis, pH and temperature changes postmortem and such changes affect meat quality traits within breeds,

►Use of locally available resources as supplementation in the dry season and their effects on meat production: Since animals lose liveweight and body condition during the dry season, potential use of locally available browse and other plant material as winter supplements and their effects on meat yield and quality is recommended, and

►Levels of meat consumption by different classes in society: To have an indication of the cholesterol and fatty acids intake by the local population, it is necessary to conduct a study on meat consumption patterns in conjunction with cholesterol and fatty acid profile analysis.

8.4. References

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Appendices

Appendix 1. V. Muchenje, K. Dzama, M. Chimonyo, J. G. Raats, & P. E. Strydom. (2007). Meat quality of Nguni, Bonsmara and Aberdeen Angus steers raised on natural pasture in the Eastern Cape, South Africa (Published in 2008 in *Meat Science*, **79**: 20-28.)

Appendix 2. Meat sensory evaluation form.

SENSORY ANALYSIS OF BEEF – 14 – 25 May 2007 9:3

Name:…….
Date:…….
Panellist no:…….

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

	Characteristics	**Rating scale**	683	347	556
1	**AROMA INTENSITY** Take a few short sniffs as soon as you remove the foil. Typical beef aroma	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense			
2	INITIAL IMPRESSION OF JUICINESS **The amount of fluid exuded on the cut surface when pressed between thumb and forefinger**	1 = Extremely dry 2 = Very dry 3 = Fairly dry 4 = Slightly dry 5 = Slightly juicy 6 = Fairly juicy 7 = Very juicy 8 = Extremely juicy			
3	**FIRST BITE** The impression that you form on the first bite	1 = Extremely tough 2 = Very tough 3 = Fairly tough 4 = Slightly tough 5 = Slightly tender 6 = Fairly tender 7 = Very tender 8 = Extremely tender			
4	SUSTAINED IMPRESSION OF JUICINESS **The impression of juiciness that you form as you start chewing**	1 = Extremely dry 2 = Very dry 3 = Fairly dry 4 = Slightly dry 5 = Slightly juicy 6 = Fairly juicy 7 = Very juicy 8 = Extremely juicy			
5	MUSCLE FIBRE &	1 = Extremely tough			

	OVERALL TENDERNESS **Chew sample with a light chewing action**	2 = Very tough 3 = Fairly tough 4 = Slightly tough 5 = Slightly tender 6 = Fairly tender 7 = Very tender 8 = Extremely tender			
6	AMOUNT OF CONNECTIVE TISSUE **(RESIDUE)** ***The chewiness of the meat***	1 = Extremely abundant 2 = Very abundant 3 = Excessive amount 4 = Moderate 5 = Slight 6 = Traces 7 = Practically none 8 = None			
7	OVERALL FLAVOUR INTENSITY This is the combination of taste while chewing and swallowing – referring to the typical **beef** flavour	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense			
8	A-TYPICAL FLAVOUR INTENSITY This refers to a flavour that is present over and above typical beef flavour, such as livery, bloody, metallic, grassy, cooked vegetables.	1 = None 2 = Practically none 3 = Traces 4 = Moderate 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense			

TICK RELEVANT A-TYPICAL FLAVOUR / S		**4. Animal-like / kraal (manure)**	
1. Livery / bloody		**5. Metallic**	
2. Cooked vegetable		**6. Sour**	
3. Pasture / grassy		**7. Unpleasant**	