Beef production, quality and fatty acid composition of non-descript crossbreed steers fed natural pasture-based diets

by

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Declaration

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

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Summary

The broad objective of the current study was to assess beef production and quality of steers fed diets formulated using locally available feed resources in communal areas of Eastern Cape Province, South Africa. A survey to identify locally available feed resources was conducted using pretested structured questionnaires administered to 47 and 48 participants from Ncorha and Gxwalibomvu communities, respectively. Crop residues (65% of all respondents), maize stover in particular, were common in both areas, with more farmers from Ncorha (70%) using crop residues than those in Gxwalibomvu (59%). Few farmers (<5%) from both communities used cereal grains and exotic herbaceous legumes (i.e., lucerne) as feed supplements. Farmers also mentioned that cattle browsed indigenous and exotic leguminous tree species, especially *Acacia mearnsii* (Black wattle) during the dry season. Most abundant feed resources in Ncorha and Gxwalibomvu communities were collected in two seasons and their nutritional composition analysed. Lucerne hay and *A. mearnsii* had the overall highest protein in both seasons while maize grain and natural pasture hay were the overall best energy sources. Cultivated pasture hay had the highest neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) and consequently had the least in-vitro dry matter digestibility (IVDMD) compared to feed ingredients. Among the crop-based feed resources, Glycine max-based commercial ration had the highest crude protein content followed by maize grain. The growth performance, carcass attributes, meat quality and fatty acid composition of crossbred steers fed *Acacia mearnsii*-based, *Medicago sativa*-based and *Glycine max*-based diets were assessed. Thirty-six 12-month-old steers were randomly allocated to the three diets (n = 12 per treatment) under feedlot conditions for 120 days. The steers fed *A. mearnsii*-based diet had lower ($P < 0.05$) average daily feed intake and average daily gain (ADG) than steers fed *M. sativa*-based and *G. max*-based diets. Steers fed the *A. mearnsii*-based diet, however, had a higher ($P < 0.05$) feed conversion ratio than steers fed *M. sativa*- and *G. max*-based diets.

Steers fed *M. sativa*-based diet had the highest (P > 0.05) warm and cold carcass weights followed by those fed the *G. max*-based and *A. mearnsii*-based diets, respectively. The *G. max*-based and *M. sativa*-based diets had positive effects on growth performance and carcass characteristics of the steers compared to the *A. mearnsii*-based diet. Diet had no effect (P > 0.05) on meat colour (L*, a*, b*, chroma and hue), pH, temperature, drip loss, shear force, crude protein and fat. Meat from steers finished on *A. mearnsii*-based diets had higher (P ≤ 0.05) moisture and ash content than meat from those finished on *G. max*-based and *M. sativa*-based diets. Meat from steers fed *A. mearnsii*-based diets had the highest cooking losses followed by those fed and *M. sativa*- and *G. max*-based diets, respectively (P ≤ 0.05). Meat from steers fed the *M. sativa*-based diet had higher (P ≤ 0.05) proportions of individual and total SFA and (n-) 3 PUFA and lower (P ≤ 0.05) proportions of linoleic acid and total n-6 PUFA than *G. max* and *A. mearnsii*- based diets. Steers finished on *A. mearnsii*-based diet had lower feedlot performance, greater gross margins, better n-3 PUFA profile and comparable meat quality to those finished on *M. sativa*- and *G. max*-based diets. The *M. sativa*-based diet had better potential to be used as alternative feeding resources for finishing cattle in a conventional feedlot system than the *A. mearnsii*-based diet.

Opsomming

This thesis is dedicated to my mothers; Prisca, Portia and Ireen

Biographical sketch

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Preface

This thesis is presented as a compilation of 6 chapters. Each chapter is introduced separately and is written according to the style of the journal South African Journal of Animal Science to which Chapter 4 and 5 is to be submitted for publication.

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Chapter 4 **Research results**
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Chapter 1: General Introduction

1.1. Background

Across the sub-Sahara, livestock production is one of the fastest growing agricultural subsectors (Thornton, 2010). It contributes up to 33% of the GDP of sub-Saharan countries (Thornton, 2010) and meets more than half of protein demands (FAO, 2003) . In South Africa, livestock production contributes one third to food and nutrient security (Avenue *et al.*, 2013). Beef cattle production in South Africa is dualistic with commercial and smallholder systems. The smallholder production system is further subdivided into small-scale commercially-oriented production system dominated by moderately-resourced farmers commonly referred to as “emerging farmers”, and subsistence-oriented production system dominated by resource-poor farmers (Avenue *et al.*, 2013). Cattle play an integral role in the communal areas including provision of draught power, manure, food, enhancing social status besides income among others (Ayalew *et al.*, 2003; Megersa *et al.*, 2013).

The Eastern Cape Province of South Africa has the most cattle raised under communal production system (SAFA, 2011). About 20% of the 14 million national herd is from the Eastern Cape Province yet the province contributes less than 1% to total national beef sales (Stats SA, 2016). The mismatch between cattle population and sales could be mainly because communal areas have low market off take rates (Musemwa *et al.*, 2010). Low off take rates are chiefly caused by inadequate supply of quality feeds, especially in the dry season, since farmers solely rely on natural pastures (Howieson *et al.*, 2014).

Seasonality of the natural pastures causes variations in its biomass and quality resulting in inconsistent cattle gains and body condition (Boone & Wang, 2007; Mapiye *et al.*, 2009a). Farmers rarely use commercial concentrate-based diets to finish their animals because their costs is prohibitive for use by resource-limited farmers (Marandure *et al.*, 2016). Few smallholder farmers use cultivated pastures and crop residues as feed supplements in the dry season (Marandure *et al.*, 2016). However, cultivation of pastures has water and financial requirements which are a constraint to the smallholder farmers in the semi-arid areas (Mccallum *et al.*, 2001). Hence it is imperative to devise a low cost, locally available feeding strategy which can improve the cattle off take rate in the communal areas. Smallholder farmers can harvest locally available natural pasture feed resources including grasses and leaves from browse tree legumes and use the as livestock feeds (Mapiye *et al.*, 2011). The most abundant browse species in the Eastern Cape Province include *Vachellia karroo* and *Acacia mearnsii* (Rouget *et al.*, 2004; Mucina & Rutherford, 2014). The antinutritional factor of concern of these indigenous browse legumes is they have high concentrations of levels of phenolic compounds, particularly condensed tannins (Naima *et al.*, 2015). High (> 8%) concentrations of condensed tannins reduce feed intake and digestibility (Ahmed *et al.*, 2005; Kozloski *et al.*, 2012). However, when moderated through cost effective methods like sun drying and wood ash treatment (Mlambo *et al.*, 2011), they enhance protein utilisation (Mlambo & Mapiye, 2015), reduce gastro-parasitic load (Geerts & Gryseels, 2001) and reduce enteric methane and ammonia emissions (Saminathan *et al.*, 2014). Furthermore, moderate condensed tannin levels inhibit lipid oxidation of unsaturated fatty acids (PUFAs) (Falowo *et al.*, 2014) and extend meat shelf life (Vasta *et al.*, 2013) and

Currently, livestock production in smallholder areas is greatly challenged by inadequate nutrition (Mapiye *et al.*, 2009b; Idamokoro *et al.*, 2016). Commercial feeds may provide adequate nutrition prior to marketing; however, they are not affordable to the resource-poor communal farmers. Feeding strategies based on cultivated pastures are also viable to communities with functional irrigation systems since most of the Eastern Cape Province is semi-arid. Browse legume trees and natural pasture grasses are inexpensive since and readily available to communal farmers. The adoption of such as feed resources can improve cattle nutrition. However, there is limited information on the effect of feeding browse tree legumes on the growth performance, carcass characteristics, meat quality and fatty acid composition of mixed breed steers finished under feedlot systems.

1.2. Justification

It is important to empower smallholder farmers with cattle feeding strategies that will improve their livelihood through increased cattle sales and consumption of healthy beef. To develop on-farm feeding regimes, knowledge of farmer socio-economic status, constrains, farming objectives, cattle management and current feeding practices, herd dynamics and productivity and the most abundant, commonly used feed resources in communities is crucial. There is inadequate information on the nutritive value of locally available feed resources making it difficult to formulate feeding programmes that promote sustainable beef production. Evaluation of the chemical composition of commonly used feed resources will ease the difficulty of formulating low cost diets.

Although browse legume trees have been widely researched on ruminants, there is limited information on the value of their leaf meal on beef production in smallholder areas of South Africa. Since consumer preferences has been shifting towards organic beef, feeding natural pasture-based legumes have the potential to produce healthful beef. The current study will bring forth information that will help eradicate food and income insecurity through extended knowledge of natural pasture-based diets, which improve their cattle off take rates, and their effect on meat quality of non-descript crossbred steers.

1.3. Objectives

The broad objective of this study was to assess beef production and quality of steers fed diets formulated using locally available feed resources in communal areas of Eastern Cape. The specific objectives were to:

i. To identify and evaluate the nutritional composition of locally available feed resources for beef production;

ii. To compare the performance and carcass characteristics of non-descript crossbred steers fed on home-mixed diets formulated using locally available feed resources to those commercial cattle finisher diet under feedlot conditions and;

iii. To compare the meat quality and fatty acid composition of non-descript crossbred steers fed home-mixed diets formulated using locally available feed resources to those fed commercial cattle finisher diet under feedlot conditions.

1.4. Hypothesis

The hypothesis tested were that:

i. The feed resources and their nutritive value used by smallholder beef farmers across the Eastern Cape are the similar;

ii. The performance and carcass characteristics of non-descript crossbred steers fed home-mixed diets formulated using locally available feed resources are similar to those fed a commercial cattle finisher diet under feedlot conditions and;

iii. The meat quality and fatty acid composition of non-descript crossbred steers fed home-mixed diets formulated using locally available feed resources are similar to those fed a commercial cattle finisher diet under feedlot conditions.

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Chapter 2: Literature review

2.1. Introduction

Livestock production is the fastest growing agricultural sub-sector of most developing countries (FAO, 2003; Thornton, 2010). There is an increasing demand for dietary protein from meat and livestock products across the globe (Delgado, 2005) stimulated by the drastic increase in population size, urbanization and improved standards of living (Davis, 2011; Herrero & Thornton, 2013). World Health Orgamisation,WHO (2003) predicted a general increase in meat consumption per capita in developing countries by 2030. South Africa, as a transition country, has an estimated 60.7kg consumption per capita by 2030 (WHO, 2003). As the population increases (Stats SA, 2016) and becomes more cosmopolitan, the South African beef industry faces various challenges, such as competitiveness in the industry, complexity of the heterogeneous multiracial and multicultural market, quality control (Vimiso *et al.*, 2012). Further among these are changing consumer needs, attitudes, preferences and consumption patterns apart from failure to meet increasing local beef demands (Poonyth *et al.*, 2001). The failure to meet consumer protein demand has compromised the food and nutrient security status.

The Eastern Cape Province (ECP) is one of the most food insecure provinces in South Africa (Musemwa *et al.*, 2015; Stats SA, 2016) yet it has the highest cattle population compared to other provinces of South Africa. The food insecurity is exacerbated by low crop production resulting from poor soils (Mandiringana *et al.*, 2007). The combination of climatic, topographic and geological features limit crop production in ECP (Ainslie *et al.*, 2002). Communities resort to livestock production as traction for crop production (Thornton, 2010). South Africa is a net importer of beef (DAFF, 2012) and most of the beef is supplied by commercial beef producers (DAFF, 2013). The commercial beef production sector constitutes 60% of the national herd while smallholder sector constitutes the remaining 40% (DAFF, 2016a).

2.2. Smallholder beef production systems in South Africa

Many a time, the term smallholder beef production is used interchangeably with small-scale beef production, resource-limited farming, subsistence cattle farming or low income farming (Calcaterra, 2013). The author mentions that there are no sole criteria to define of smallholder beef production rather a multi-criteria definition which involves the farming system, landholding size and income bracket. Although Oettle *et al.*, (1998) asserts the lack of consensus on the definition of smallholder farming in South Africa, the sector is dichotomous, existing as small-scale and communal production systems (Palmer & Ainslie, 2006). In the context of this research, communal beef producers are considered as those who hold small farms (< 12ha) where individuals have open access to natural resources. The farmers own a small herd (<10 cattle), and have limited use of technology and external inputs (Palmer & Ainslie, 2006). They have limited access to services and credit with most of their market interaction taking place at informal local markets, for which they produce local or traditional products. They routinely face high transaction costs in respect of securing quality inputs and gaining market recognition for quality outputs. They have little formal education and training and they keep their animals on communal land. Communal livestock farming is, in most households, a family enterprise that practises either subsistence production mixed with little or no commercial production. The family is the major source of labour, and livestock production is often the main source of income (FAO, 2009).

Small-scale farmers, sometimes referred to as emerging farmers, are previously underprivileged farmers that are determined and have the capacity to expand and develop into commercial farmers (Ramdeen, 2014). They are black farmers who were previously denied land access and the opportunity to farm profitably by the Apartheid system. Emerging farmers have very limited policy support and their challenges are predicted to persist if they are not addressed (Kirsten & Van Zyl, 1998). With better opportunities and more knowledge, the same farmers can produce above subsistence levels and are be more market oriented (Calcaterra, 2013).

2.3. Importance of smallholder production system in South Africa

The smallholder beef production system owns 40% of the national cattle herd (DAFF, 2016a). Apart from being a source of income, the beef production sector improves food security in smallholder communities through food provision. The smallholder sector could potentially bridge the short supply from the commercial sector (DAFF, 2016b). South Africa is a net importer of beef (DAFF, 2016b) and the smallholder sector has the potential to make it a self-sufficient state in terms of beef production. The sector creates employment, although informal, to the surrounding population through casual labour. Smallholder farming contributes to socio-political stability in the areas they exist (Delgado et al., 2001). Because smallholder systems are usually crop-livestock mixed systems, livestock production contributes to crop production through provision of draught power and manure (Mlambo & Mapiye, 2015). Activity in smallholder farms stimulate business activity in the areas surrounding the smallholder farms through back and forth trades (Tshuma, 2012). Because smallholder production uses small sizes of land, farmers can collectively provide for a nation with land scarcity like South Africa (Tshuma, 2012). Before 1979, Vietnam imported more than 90% of its food but it implemented schemes to enhance smallholder farming thus its self-sufficiency in present day (Pinda, 2008).

2.4. Constraints of smallholder beef production

2.4.1. *Variability of quality and quantity of feed resources*

Grazing pasture is affected by geoclimatic factors. Biomass in semi-arid areas lose nutritive value and palatability during the dry season (Abusuwar & Ahmed, 2010). The cattle body condition and weight again is affected by such a phenomena (Mapiye et al., 2009a). Farmers who rely on pasture for feeding their animals ought to understand and utilise the rainfall patterns to be able to harness the greatest value of the pasture. This scenario will allow only one selling season per year, making beef production ill-viable.

2.4.2. *Improper rangeland management techniques*

Communal rangeland management practices in the smallholder areas give individuals unlimited access to rangeland resources (Moyo et al., 2008) as long as they have grazing rights from their traditional leader (Cousins, 1996). This scenario results in mismanaged resources since it is difficult to control high stocking densities, grazing habits and diseases. High stocking rates result in land degradation leading to soil erosion and poor soil quality ensuing low quantity forage of poor quality (Scoones & Graham, 1994). This consequently compromises the growth and reproductive performance of the herd and ultimately affects the market value of the animals (Mapiye, 2009). Knowledge of sustainable rangeland management practices is gradually being disseminated among communal farmers, however, needs to be more wide spread.

2.4.3. *Diseases and parasites*

Poor herd health account for the majority of mortalities in communal areas (Mbati et al., 2002). Tick borne diseases, like babeiosis and anaplasmosis, are prevalent in most communal areas and lower productivity and increase cattle immortality (Mbati et al., 2002). Sungirai et al., (2016) reported a 29% mortality rate owing to tick-borne diseases. Although farmers' perception on tick-worry and tick-borne diseases in communal areas is not well documented (Sungirai et al., 2016), the resource constraint farmers can neither afford the commercial acaricides nor change them time and again to prevent tick resistance to acaricides (Muchenje, 2007). It is essential for government to initiate tick control and tick-borne disease training programmes as well as selection programmes for tick resistance to reduce mortalities due to tick-borne diseases.

2.4.4. *Limited cattle production skills and poor breeding practices*

Farmers in communal areas have limited knowledge of appropriate cattle production systems that suit their rangeland types, socio-economic status and micro-climate (Mapiye, 2009). Lack of knowledge of appropriate breeds and breeding techniques adversely affects cattle production amongst communal farmers. Non-descript crossbreds, sometimes referred to as mixed breeds, are most prevalent in these areas. Although there are small populations of local breeds like Nguni, Afrikaner, Drankensberger and Brahman (Kunene-Ngubane et al., 2014), their purity is debatable. Non-descript breeds and impure dominant breeds are a result of uncontrolled mating or policies implemented by organisations which promote use of exotic beef breeds (Bester et al., 2003). Farmers' lack of sire-dam-offspring records exacerbates the unrestrained mating leading to inbreeding and consequently inbreeding depression which results in poor beef productivity (Bayer et al., 2004). On one hand, productivity of the exotic breeds like Aberdeen Angus and Shorthorn is negatively affected by the harsh environmental conditions of communal areas in semi-arid regions (Bester et al., 2003). On the other hand, indigenous breeds like the Nguni are small framed and do not yield much beef although they are well adapted (Mapiye, 2009).

Some synthetic breeds can be both hardy and beefy but might not be readily affordable to farmers in communal areas. Therefore, mixed breeds solve this conundrum of commercial value and adaptability. It is crucial to assess the level of knowledge of the communal farmers on cattle production and cattle breeds and breeding to appropriately design sustainable beef production systems.

2.4.5. *Youth rural to urban migration*

In recent times, the young folk is migrating to urban areas for various socio-economic factors which are mainly educational pursuance, search for employment and trivially due to lack of social amenities (Ango et al., 2014). The gap created by this migration compromises cattle production because the older folk left in the communal areas cannot execute the physical work required in cattle production. In Nigeria, researchers have argued that although the mitigation dampens the agricultural productivity, the income generated improves the standard of living of the rural folk and alleviates the financial burden (Ango et al., 2014). There is limited literature to suggest a similar school of thought in South Africa.

2.4.6. *Low cattle offtake*

Cattle offtake rates are usually used for herd productivity evaluations together with production potential and production efficiency (Mapiye et al., 2009a). Cattle offtake rate is the proportion that is sold in a herd for income (Baptist, 1988). This proportion indicates the income derived from livestock. Coetzee et al., (2005) relate offtake rates to market access. Several authors have documented low offtake rates in communal farming systems of developing countries. Nkhori, (2004) reported cattle off take rates of between 5 and 10% in Mahalapye district in Botswana. Coetzee et al., (2005) also mentioned offtake percentages of less than 10% in Eastern Cape Province, South Africa. Enkono et al., (2013) recorded offtake rates of around 2% in the northern communal province of Namibia. In Ethiopia, cattle offtake rates was also used as a measure of household food access which related to food security (Megersa et al., 2013). The reasons for low off take percentages are discussed by several authors and are almost similar across communal areas. Coetzee et al., (2005) stated poor condition of animals as the major reason for low offtake rates. Farmers would opt not to sell their animals than receiving unsatisfactory prices from buyers. Meagre animals are lowly priced because their condition indicate poor meat quality (Musemwa et al., 2010).

Although age of the animals at point of sale is not part of the classification system, it directly influences the commercial value consequently affecting the marketing of animals. Coetzee et al., (2005) iterated farmers sell their animals for petty cash to use in times of emergencies. Animals way past their maturity have tough meat and thus are lowly priced. Soji et al., (2015) reported that most animals slaughtered at a throughput abattoir they surveyed had carcass class C. This reflects that farmers keep their animals too long before slaughter, which can be a result of poor feed resources resulting in retarded growth.

High transaction cost also influences low offtake rates (Ndoro et al., 2015). Communal farmers are in remote areas and the further they are from the satellite towns, the greater the cost of transport (Musemwa et al., 2010). At the end of each transaction, farmers have to foot the bill incurred in selling their animals (Wollny, 2003). With such hiked expenses, farmers opt to keep wealth than gain little monetary value from it. Farmers also lack information on market prices and market trends and inefficient communication channels hinder the flow of vital information to respective farmers (Bailey et al., 1999). In recent times, however, communication has become relatively affordable and network coverage is wide spread. Technological advancement has also brought about timeless information to the palm of our hands hence news about product price indices are now almost readily available to the farmers.

Many a time, the animals sold by smallholder farmers do not meet the requirements and prerequisites of the modern-day beef market due to feed inadequacy. Most farmers are unable to feed their animals to realise their genetic potential because of the lack of feed and feed resources in the semi-arid regions they farm in. Mapiye et al., (2009) reported a feed shortage in communal areas of the Eastern Cape Province. The inadequate feed supply is mainly caused by erratic rainfall patterns in the region. Fluctuations in rainfall patterns causes variations in yield and quality of natural pasture biomass (Boone & Wang, 2007). Most farmers in this region rely on protein-deficient natural pasture and browse tree legume species as feed for their animals. Very few can afford commercial feed or feed supplements. In this regard, the farmers need alternative feed and feeding strategies to be able to improve their animals' nutritional status and thus improve offtake rate.

Commercial beef producers use synthetic growth stimulants to keep the feed conversion efficiencies profitable; which are probiotics, prebiotics and synbiotics (Gaggìa et al., 2010). These growth stimulants are designed to regulate intestinal microbial homeostasis (Salminen et al., 1996), facilitate the expression of bactriocins (Mazmanian et al., 2008) and activate enzymatic activity inducing nutrient absorption thus improving nutrient utilization (Hooper et al., 2002). Furthermore, beef production on a commercial scale uses high quality animal feed, ad libitum, for the best performance of their animals. The commercial farmers have the resources to acquire these feeds and supplements making their offtake rates much higher than those from resource-poor smallholder farmers. To improve nutrition of their beef cattle, smallholder farmers could utilise low cost browse tree legume species that are abundant in their area.

2.5. The potential of legume tree leaf meal as cattle finisher diets

Indigenous legume species found in Southern Africa include *Dichorystychs ainera, Julbernadia globiflora, Colophospermum mopane, Piliostigma, Pterocarpus* and *Acacia* genera (Van Wyk et al., 2000; Mlambo et al., 2004). In recent times, Vachellia karroo has mostly been utilised because of its high crude protein (Idamokoro et al., 2016). Researchers found the benefits of using Vachellia karroo leguminous browse tree species on growth performance, stress resistivity, fatty acid composition, meat quality and of farm animals (Mapiye et al., 2009c, 2010, 2011c, b; a; Xhomfulana et al., 2009; Ngambu et al., 2013). However, Vachellia karroo is spinescent thus its utilisation is greatly compromised (Nyamukanza & Scogings, 2008). Greater utilisation can be achieved by manually removing the thorns (Mapiye, 2009). Wilson & Kerley, (2003) reported that bushbucks and Boer goats attained higher intakes following manual removal of the thorns from the branches. Be that as it may, removing thorns or harvesting and preparation for leaf meal for large herds is very tedious and hence not feasible (Mapiye, 2009). Thornless Acacia mearnsii (Black Wattle) can be used as an alternative to Vachellia karroo. Black wattle is ranked third invasive species in South Africa. Its existence is a major threat to water resources (Dye et al., 2001) and arable land for agriculture. Organisations like World Wide Fund for Nature and Department of Water Affairs are clearing dense stands of Black Wattle because of the threat they pose on biodiversity and water resources (Richardson & Van Wilgen, 2004; Waal et al., 2012). Communal farmers are also clearing the encroaching thickets of the browse tree to make space for agriculture and settlement to cater for their increasing household sizes as well as for wood fuel. Diverting efforts and research from the riddance of A. mearnsii as a weed to utilisation as cattle feed will reduce encroachment and improve forage and animal production (Marandure et al., 2016).

2.6. Nutritional composition of *Acacia mearnsii* leaf meal

Acacia mearnsii is a valuable source of nutrients in the semi-arid sour veld of the Eastern Cape Province where quality forage is a major constraint. Like most Acacia species, A. mearnsii is believed to have a high crude protein content although it is not documented in literature. Acacia mearnsii, like most leguminous browse species, contains polyphenolic compounds (Max et al., 2007) which are detrimental to nutrient digestion and absorption if the leaves are not detannified. Black wattle leaves contain between 120 g/kg and 140 g/kg DM of condensed tannins (Max et al., 2007). Such high concentrations bestow an astringent, bitter taste to the leaf meal consequently supressing voluntary feed intake, reducing digestion rate and absorption (Mlambo et al., 2004; Rubanza et al., 2005; Waghorn, 2008) . Condensed tannin concentrations between 20 g/kg and 60 g/kg DM have been found to have positive and healthful effects on ruminant growth and product quality. Mapiye et al., (2011b) concluded that inclusion of Acacia karroo, a tanniferous supplement, in Nguni cattle diets can meliorate the fatty acid composition of beef.

2.7. Detanninification of *A. mearnsii* foliage

Numerous methods can be used to reduce the adverse effects of phenolic compounds in A. mearnsii. These methods include the use of oxidising agents (such as potassium dichromate and potassium permanganate), use of tannin-binding compounds (such as polyethylene glycol and polyvinyl-pyrrolidone), metal ions, alkalis (urea, sodium hydroxide and potassium hydroxide), wood ash/charcoal, microbial degradation, and drying (Makkar, 2003; Ben Salem et al., 2005; Vitti et al., 2005). The major disadvantages of using metal ions, alkalis and oxidising agents is the large losses of soluble nutrients and it can be hazardous to animals if mismanaged (Ben Salem et al., 2005; Vitti et al., 2005). Although effective, the cost and availability of microbial enzymes and tannin-binding compounds makes their use impractical and uneconomic under the communal beef production systems (Makkar, 2003; Ben Salem et al., 2005). Wood ash and charcoal are inexpensive and locally available products (Ben Salem et al., 2005; Mlambo et al., 2011), but may not be available in large quantities for sustainable utilisation in smallholder areas. Oven and freeze-drying methods require expertise, sophisticated equipment and energy (Dzowela et al., 1995), which are not available in most rural communities. Though moderately effective compared to other methods, sun-air-drying is a cheaper and user-friendly technique that makes use of locally and abundantly available resources (Dzowela et al., 1995). Sun-air-drying can, therefore, be a more acceptable and feasible alternative for the resource-limited cattle producers (Dube, 2000).

Sun-air-drying improves degradability and digestibility of leguminous tree leaves (Hove et al., 2001), and animal performance compared to fresh leaves (Rubanza et al., 2005, 2007; Vitti et al., 2005). Improved performance of animals on dried tree legume diets can be attributed to increased nutrient concentration, improved utilisation of endogenous nitrogen in the rumen and change in the solubility of the protein increasing the bypass protein content, and amount and quality of post-ruminal amino acid absorption of the leaf meal (Ben Salem & Smith, 2008).

Sun-air-drying improves palatability of some browse species (Leng & Fujita, 1997). In practice, sun-air-drying reduces astringency of Acacia species, thus increasing its intake by ruminants (Ben Salem et al., 2005). Further research is, however, required to ascertain the effect of feeding sun-air dried A. mearnsii leaf meal on beef cattle performance under feedlot conditions, beef yield and quality.

Table 2.1: Mineral concentration of A. mearnsii foliage

Mineral	Value
Nitrogen (%)	2.72
Phosphorus (%)	0.095
Potassium (%)	0.689
Calcium (%)	0.562
Magnesium (%)	0.200
Sodium (%)	0.083
Manganese (mg/kg)	88.15
Iron (mg/kg)	266.84
Copper (mg/kg)	7.58
Zinc (mg/kg)	16.09

Source: Dovey, (2005)

2.8. Effect of leguminous browse on feed intake and growth parameters

Researchers have found an increase in average daily gains and slaughter weights on ruminants fed on leguminous browse tree supplements owing to the increased nutrient utilisation facilitated by tannins in legume browse tree leaves, pods, fruit or bark. The tannins are believed to selectively hydrogen bind with the proteins forming a hydrophilic, tannin-protein complex. Simple linear structure proteins for instance casein, easily degrades in the rumen and less than 10% reach the small intestine (McDonald & Hall, 1957). The treatment of feed with formaldehyde protects linear proteins from microbial attack in the rumen, mimicking slowly degradable protein Ferguson et al., (1967). This improves protein absorption in the small intestine consequently improving growth and production. Zelter et al., (1970) also demonstrated that formaldehyde inhibited protein fermentation in the rumen increasing the percentage of bypass protein in vitro. Nishimuta et al., (1974) also showed that treatment with formaldehyde of feedstuffs increased the quantities of amino acids reaching the small intestine. On the contrary, Ashes et al., (1984) believed formaldehyde crosslinks with essential amino acids via covalent bonds making them unavailable for uptake in the small intestine. Unlike formaldehyde-protein complex, the tannin-protein complexes are assumed to dissociate in the ileum allowing efficient protein digestion and uptake (Mlambo and Mapiye, 2015). Several researches have reported increased average daily weight gains on ruminants supplemented with tannin-rich feeds or tannin extract. Mapiye et al., (2009b) reported heavier carcasses of steers fed Vachellia karroo leaves compared to those that relied merely on the pasture. Similarly, Nyamukanza and Scogings, (2008) found that goats fed V. karroo leaves had higher ADG compared to those fed a control diet. Moderate tannin levels in feeds also increased milk yield and milk composition.

2.9. Effect of leguminous browse on animal health

Smallholder ruminant production in semi-arid areas is arguably constrained by the high prevalence of diseases and gastro-parasites. These causes loses to the sector through mortalities and below par productivity owing to chemotherapeutic drugs (Mlambo & Mapiye, 2015). Tanniniferous forages were found, by several researchers, to reduce nematode burden, egg fecundity and hatchability in the gastro-intestinal tract by binding with proteins and glycoproteins in the rumen and the gastro-intestinal mucosa (Geerts & Gryseels, 2001; Min et al., 2003; Muller-Harvey, 2006; Max et al., 2007; Waghorn, 2008; Mlambo & Mapiye, 2015). Condensed tannins were found to reduce adult population of Haemonchus contortus in lambs (Heckendorn et al., 2006; Cenci et al., 2007) and goats (Shaik et al., 2006) and also lower the fecundity of Cooperia curticei (Heckendorn et al., 2006). Prophylactic tannin-rich forages will ameliorate animal production, fertility, ovulation rates, wool growth and milk production in the semi-arid resource constraint regions of South Africa (Ram & Barry, 2005). Several authors have reported the gastro-therapeutic effects of black wattle condensed tannins on ruminants (Max et al., 2007, 2009; Max, 2010; Minho et al., 2010; Hassanpour & Mehmandar, 2012; Costa-Júnior et al., 2014). Apart from parasitic control, tannin-rich forages or tannin extracts are known to reduce bloat occurrences as well as methanogenesis in ruminant’s on pasture, in vivo and in vitro (Min et al., 2003; Waghorn, 2008; Patra & Saxena, 2011).

2.10. Effect of leguminous browse on carcass quality

Beef carcasses in South Africa are classified using conformation, subcutaneous fat, sex and age (SAMIC, 2006). Conformation is a measurement of the roundness of the carcass and is measured on a scale from 1 to 5 (1 = very flat, 2= flat, 3 = medium, 4 = round, 5 = very round). Conformation is an indication of the quantity of meat deposited as muscle during growth, in other words, the body condition score (BCS). Subcutaneous fat is a measurement of the thickness of the adipose tissue beneath the skin. It is a measurement from 0 to 6, (0 = no visible fat, 1 = very lean, 2 = lean, 3 = medium, 4 = fat, 5 = over-fat, 6 = extremely over-fat). The adipose tissue is to store energy in the form of triglyceride and reduces heat loss (Lawrence et al., 2012). It also reflects on the nutrition of the animal in terms of the net energy system. Carcases from bulls that had 1-2 permanent incisors or more are marked with a MD stamp to alert buyers to expect a different taste and colour. Age is determined by the number of incisors at slaughter. Letters are used to categorise the carcases (A = 0, AB = 1-2, B = 3-6, C = 6+). The age class informs on the tenderness of the meat.

Dietary condensed tannins have a positive effect on carcass attributes. Mapiye et al., (2009b) observed better BCS, higher carcass weights (warm and cold) and larger eye muscle area of steers supplemented with sweet thorny wattle leaf meal compared to those that entirely relied on rangeland. Similar findings were reported by Nyamukanza and Scogings, (2008) on goats fed coppices of *Vachellia karroo*. Information on the effect of *Acacia mearnsii* tannins on carcass characteristics is relatively limited and thus further research is essential.

2.11. Effect of leguminous browse on meat quality

2.11.1. Fatty acid profiles

In recent times, meat consumers are increasingly conscious about the healthfulness of the meat they eat. Healthy meat is considers to have a fair balance of adipose tissue and fatty acids so as not to cause chronic illnesses like obesity, diabetes, some cancers, coronary thrombosis and cardiovascular disease (Lawrie & Ledward, 2006; Ruiz-rodriguez et al., 2010). The public’s general perception of fat is not favourable, however, some nutrients can have essential health benefits (Ruiz-rodriguez et al., 2010).

Dietary fat is a source of essential fatty acids which can be used as functional ingredients since their consumption is associated with good health (Simopoulos et al., 1999; Muchenje, 2007; Ruiz-rodriguez et al., 2010; Turner et al., 2015; Mlambo & Mapiye, 2015).

Fatty acids act as basic units of lipids and are aliphatic monocarboxylic acids. They exist as saturated or trans fatty acids (SFA), monounsaturated or polyunsaturated fatty acids (PUFAs). They are also long chain fatty acids (LCFA) with tails of 16 or more carbons and short chain fatty acids. LCFAs include PUFAs which contain two or more double bonds. The PUFAs have two families; omega-3 and omega-6 (n-3 and n-6), which are both essential fatty acid group considering humans cannot synthesise PUFAs with a double bond of position 6 or lower (Ruiz-rodriguez et al., 2010). The most naturally abundant PUFA is linoleic acid. Green forages have content high levels of α-Linoleic acid (ALA) which can be endogenously desaturated and elongated to n-3 long chain fatty acids (Razminowicz et al., 2006) for instance eicosapentaenoic acid (EPA), docospantaenoic acid (DPA), docosahexaenoic acid (DHA) (Muchenje, 2007). The products of the desaturation of ALA have anticarcinogenic properties and facilitate functionality of nervous, vision and immune systems (Beharka et al., 1997; Enser et al., 1998). According to Wood et al., (2008), increasing the intake of ALA (18:3n-3) and decreasing the intake of ALA (18:2n-6) promotes the desaturation of ALA. Therefore, the ratio of SFAs to PUFAs and n-3 to n-6 is an important measure of nutritional quality and healthfulness of meat.

Conjugated Linoleic Acids (CLAs) is yet another group of FAs that has gained significant attention because of their ability to reduce the risk of lifestyle-related diseases. This group represents a collection of geometric isomers of LA with double bonds at position 8 and 10, 9 and 11, 10 and 12, 11 and 13 which occur as cis-trans, cis-cis, trans-cis or trans-trans (Silva et al., 2014). It is a product of incomplete bio-hydrogenation of LA in the rumen (Bhattacharya et al., 2006) and thus ruminant products have high content of CLA (Schmid et al., 2006).

Table 2.2: Fatty acid composition of Acacia mearnsii leaves

	Source	
Fatty Acid (g/100g)	**Mapiye et al., (2011a)**	**Staerfl et al., (2011)**
14:0	1.88	3.00
14:1c9	0.31	0.19
15:0	0.36	0.58
15:1c10	0.15	0.017
16:0	24.22	30.8
16:1c9	2.95	
17:0	0.94	2.87
17:1c9	0.11	0.29
18:0	16.28	26.3
18:1c11	1.46	
18:1c9	30.69	
18:1t11	1.87	9.61
18:2c9t11	0.32	0.16
18:2*n*-6	6.32	1.51
18:3*n*-3	2.59	0.15
20:0	0.16	0.18
20:1c11	0.05	-
20:1*n*-9	-	0.08
20:3*n*-3	0.63	0.02
20:3*n*-6	-	0.04
20:4*n*-6	3.74	0.04
20:4*n*-3	-	0.00
20:5*n*-3	1.81	0.00
22:0	0.31	-
22:2*n*-6	0.33	-
22:5*n*-3	2.43	-
22:6*n*-3	0.11	-
Total SFA	44.15	64.2
Total MUFA	37.58	32.9
Total PUFA	18.27	2.87
Total *n*-6	10.71	-
Total *n*-3	7.56	-
PUFA/MUFA	0.51	0.09
PUFA/SFA	0.42	0.04
n-6/*n*-3	1.44	16.1

The fatty acid composition of meat depends primarily on breed and feeding regime (Muchenje, 2007). Some bovine genotypes exhibit better gene expression that favours adipose tissue accretion compared to others (Choi et al., 2000). Forage-raised beef exhibit a more positive n-3 to n-6 ratio than concentrate-raised (Baublits et al., 2006; Razminowicz et al., 2006). Gatellier et al., (2005) observed higher proportions of n-3 PUFA in beef from pasture finished cattle compared to that from cattle finished with maize silage and hay. Mapiye et al., (2011a) reported high concentration of ALA is steers on natural pasture supplemented tanniferous Acacia karroo. The effect of tannins on meat fatty acid profiles are, however, inconsistent in literature. Table 1 shows the profiles of beef supplemented with condensed tannins from Vachellia karoo (Mapiye et al., 2011a) and Acacia mearnsii (Staer et al., 2011). Morales and Ungerfeld, (2015) reviewed the use of tannins to manipulate the ruminant milk and meat fatty acid composition. While Benchaar and Chouinard, (2009) reported no effects in bovine milk, Dschaak et al., (2011) and (Kälber et al., 2013) reported an increase in ALA and total trans C18:1 using quebracho and buckwheat tannins respectively.

Although Staerfl et al., (2011) observed decreased rumenic acid (RA) in beef and (Aprianita et al., 2014) reported no effect on milk fatty acid composition with Acacia mearnsii tannin on the fatty acid profile of steers, it is believed that black wattle has beneficial effects to the fatty acid profile of beef.

2.11.2. Meat colour

Meat colour is considered the single most important meat quality attribute influencing purchase of meat because it gives a perception of the freshness of meat (Mlambo & Mapiye, 2015). Consumers associate bright red colour with fresh meat and pale brown with stale or spoiled meat (Priolo et al., 2005). Meat colour is determined by four chemical forms of myoglobin; deoxymyoglobin, oxymyoglobin, carboxymyoglobin and metmyoglobin (AMSA, 2012). Deoxymyoglobin results in deep purplish-red colour typical of vacuum packaged meat. Oxygenation of deoxymyoglobin yields oxymyoglobin which has a bright red colour or metmyoglobin which gives meat a brown colour (Lawrie & Ledward, 2006; AMSA, 2012).

1: Oxygenation of Deoxymyoglobin to Oxymyoglobin; 2: Oxidation of Oxymyoglobin to Metmyoglobin. Reaction is not thermodynamically feasible; 3: Oxidation of Oxymyoglobin to Metmyoglobin then reduction to Deoxymyoglobin; 4: Oxidation of Deoxymyoglobin to Metmyoglobin; 5: Carboxylation of Deoxymyoglobin to

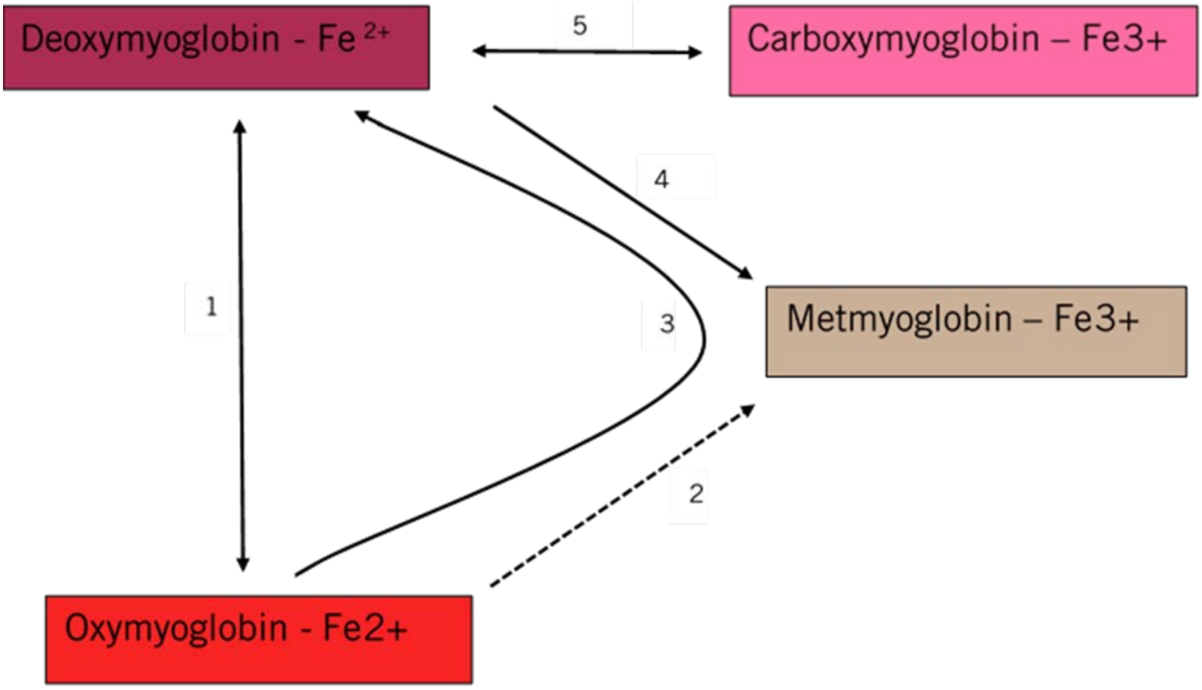

Figure 2.1: Myoglobin redox interconversions on the surface of meat

Carboxymyoglobin. Sources: (Mancini & Hunt, 2005; AMSA, 2012)

Meat colour is commonly quantified by the CIE-L* (black and white), a* (red-green) and b* (blue-yellow) values. Meat lightness is represented by L* which ranges from 0 to 100 whilst a* and b* represent the chromatic components of meat and range from -120 to +120 (Priolo et al., 2001; Girolami et al., 2013). Studies by Mapiye et al., (2010) revealed that meat from steers supplemented with a Vachellia karroo had the highest redness (a*) and lightness (*L) coordinates than that from steers supplemented with sunflower seed cake. Ngambu et al., (2013) had similar findings for meat lightness from goats supplemented with Vachellia karroo and Luciano et al., (2009) reported improved meat colour stability from lambs fed Schinopsis lorentzii. Meat redness might be higher due to the high dietary iron intake by animals on condensed-tannin rich supplement. Luciano et al., (2009) reported meat colour stability of refrigerated lamb from animals given a quebracho tannin supplement. On the same note, condensed tannins interfere with the synthesis of Vitamin B12 and thus the light colour. Overall, condensed tannin rich feedstuffs increase meat redness and lightness (Mlambo & Mapiye, 2015). Although there is there is information of the role of tanniferous plant bioactives, there is not much documented on condensed tannins from Acacia mearnsii.

2.11.3. Water holding capacity, drip loss and cooking loss

The amount of fluid exudate from unfrozen, uncooked meat is water holding capacity, from thawed meat is drip loss and shrink from cooking is cooking loss (Lawrie & Ledward, 2006). The spaces between the thick filaments of myosin and the thin filaments of actin hold water in a muscle (Lawrie & Ledward, 2006). Water holding capacity and drip loss are predominantly controlled by pH (Zhang et al., 2005) which is influenced by pre-slaughter stress. Ration nutritional composition have very little or no effect on water holding capacity, drip loss and cooking loss. Although the attributes contribute to the flavour of the meat owing to the juiciness, there is no evidence in literature that feeding systems affect WHC.

2.11.4. Meat tenderness and pH

The overall impression of meat tenderness to a consumer includes three aspects; the ease of penetration of meat by teeth, the ease of meat breaking into fragments and the residue left after chewing (Lawrie & Ledward, 2006). The degree of tenderness is influenced by the proportions of intramuscular proteins of the collagen, myofibril and the sarcoplasm (Lawrie & Ledward, 2006). Meat tenderness varies across breeds, gender, age and ante mortem stress (Muchenje, 2007) and also with the changes of myofibril protein structure from the time of slaughter until consumption (Muir et al., 2000). Prior to consumption, cooking time, temperature and use of species can affect meat tenderness. Meat tenderness is measured by the force that is required to tear it apart, shear force tested by Warner-Bratzler Shear Force (WBSF) test.

There are no significant difference in WBSF values, in literature, of beef from different feeding strategies. Mapiye et al., (2010); Mapiye et al., (2011c) and Liu et al., 2016) found no significant differences on the WBSF values of meat from animals supplemented with condensed tannins. Although tannins are expected to improve tenderness due to marbling, meat toughness is greatly influenced by prior slaughter handling and slaughter procedures.

Ultimate pH influences meat flavour and tenderness and is related to the glycogen stores in the muscle (Lawrie & Ledward, 2006; Muchenje, 2007). Pre-slaughter handling stress causes muscular glycogen depletion thus increasing ultimate pH which consequently decreases flavour intensity (Lawrie & Ledward, 2006). Feeding regimes have no effect on the ultimate pH levels in meat. Although Muir et al., (1998) hypothesised a significant difference in ultimate pH between grass-fed beef and grain-fed beef, French et al., (2000) and Razminowicz et al., (2006) observed no differences.

2.12. Summary

Smallholder beef production systems have the potential to yield high volumes of quality beef. Beef yield in these resource constraint production systems is limited due to poor and inadequate nutrition in the dry season. Research on production potential, production efficiency, nutritional status of locally available feed resources in communal rangelands and the effect of utilizing them as finisher diets on cattle performance is, therefore, paramount. Although A. mearnsii leaf meal has potential as a ruminant feedlot finisher feed, its value for beef production from cattle grazing low quality rangelands has not been determined. The broad objective of the current study was to evaluate beef production in small-scale communal areas and the potential of A. mearnsii in improving beef production in the Eastern Cape Province of South Africa.

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Chapter 3: An inventory of feed resources for smallholder beef production in the Eastern Cape Province, South Africa

Abstract

The objective of the current study was to identify and assess the nutritional composition of feed resources used for beef cattle production in the smallholder communities of the Eastern Cape Province. Data on available feed resources were collected using pretested structured questionnaires administered to 47 and 48 participants from Ncorha and Gxwalibomvu communities, respectively. The identified cattle feed resources were sampled in wet and dry seasons and analysed for nutritional composition. Farmers from both communities grazed their cattle communally on natural pastures throughout the year. The majority (91%) of the interviewees indicated they used feed supplements during the dry season. Crop residues (65%), maize stover in particular, were common in both areas. Few farmers (<5%) used cereal grains and exotic herbaceous legumes as feed supplements. Farmers also mentioned that cattle browsed leguminous tree species, especially *Acacia mearnsii*. Results from the nutritional composition analysis indicate that Lucerne hay in the dry season had the highest crude protein content followed by Lucerne hay in wet season, *A. mearnsii* in the dry season and *A. mearnsii* in the wet season, respectively ($P < 0.05$). Cultivated pasture hay had the highest neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) contents in the dry season compared to other feed ingredients. Among the crop-based feed resources, *Glycine max*-based commercial ration had the highest ($P < 0.05$) crude protein content followed by maize grain harvested in 2015. It was concluded that natural pasture hay, crop residues, Lucerne, *A. mearnsii* and cereal grains were the major feed resources used for beef production in the surveyed areas.

Keywords: smallholder, natural pasture, low cost feed resources, improved grasses, browse legumes

3.1. Introduction

Food and nutrition insecurity is currently a principal threat to the livelihoods of people living in South Africa, especially in the smallholder sector (Altman *et al.*, 2009; Tshuma, 2012). The Eastern Cape (EC) Province is the most poverty stricken and least food secure province in the country (Musemwa *et al.*, 2015; Stats SA, 2016). The semi-arid climate and erratic rainfall patterns in the province contribute immensely to poor crop production (Benhin, 2006; Muller & Shackleton, 2013). In this regard, smallholder farmers in the EC Province resort to livestock agriculture for livelihoods (Bester *et al.*, 2003; Musemwa *et al.*, 2007). The EC Province is the premier livestock region in South Africa comprising almost 40% of the 5.7 million cattle in the smallholder sector (DoTP, 2008; DAFF, 2013). The majority of these herds are non-descript crossbreds and Nguni breeds raised mostly on natural pasture throughout the year (Mapiye *et al.*, 2009b). Natural pasture biomass and nutritive value, however, vary with seasonal fluctuations in temperature and rainfall (Boone & Wang, 2007) resulting in inadequate and inconsistent nutrient supply for cattle. Crude protein is the most limiting nutrient for the cattle raised on natural pasture during the dry season (Mapiye *et al.*, 2010b). Consequently, weight gains, carcass yield and quality are reduced resulting in low offtake rates (Mapiye *et al.*, 2009a).

Protein supplements are essential for finishing beef cattle prior to marketing in the dry season. Although commercial concentrate-based feeds are available, they are not affordable to resource-constraint smallholder farmers. Cultivated pasture legumes are an option but, they are expensive to establish and maintain as they also compete for land with food crops (Mapiye *et al.*, 2011). Natural pasture resources including grasses, shrubs and browse tree species have potential to improve cattle nutrition in communal areas because they are cost effective and readily available (Mapiye *et al.*, 2011; Mlambo & Mapiye, 2015; Idamokoro *et al.*, 2016). Before designing cattle-based feeding regimes, it is essential to consider the socio-economic profiles and traditional practices of the communal farmers. Moreover, it is crucial to make a holistic inventory of the available feed resources profiling their relative sources, extend of scarcity and nutritive value. The objective of the current study was to identify and evaluate nutritional composition of locally available feed resources used for beef production in Ncorha and Gxwalibomvu communities in the Eastern Cape Province of South Africa.

3.2. Materials and methods

3.2.1. Site description

The study was conducted in Ncorha and Gxwalibomvu communities in the Instika Yethu municipality of the Chris Hani district in Eastern Cape Province, South Africa. The communities were purposively selected since they are beneficiaries of the National Agricultural Marketing Council (NAMC) custom feeding program. The aim of the custom feeding program is to improve the cattle offtake rates through improved feeding. Under the program, cattle producers are organised into cooperatives, and structures imitating conventional feedlot pens are erected in their communities. Individual cooperative members bring their cattle to the feedlot pens where they are fattened using subsidised commercial feed purchased by the NAMC.

Ncorha village is 31° 49’ 0” S and 27° 44’ 0” E. The climate is predominately semi-arid, with annual rainfall ranging between 400 and 600mm. Average annual temperature ranges from 14 to 20°C. Gxwalibomvu community, near Cofimvaba, which is 32° 1’ 12” S and 27° 45’ 6” E. The area receives an annual rainfall of between 500 and 600 mm. The wet season stretches from late September to late April and the dry season is from early May to mid-September. Both Ncorha and Gxwalibomvu communities are classified as Tsomo Grassland, which is a sour veld characterised by thornveld or open grassland (Mucina & Rutherford, 2014).

3.2.2. Farmer selection and data collection

A pre-tested questionnaire was administered to a total of 95 farmers (46 from Ncorha and 48 from Gxwalibomvu) by trained enumerators in the local language, IsiXhosa. The snowball sampling technique was used to identify the participants on condition that they owned at least five animals and had a potential of selling at least one animal per year. The survey was carried out under the Human Ethical clearance approved by Stellenbosch University Research Ethics Board (SU-HSD-000505). The questionnaire captured data on household socio-demographics, livestock herds and compositions, common cattle breeds, offtake patterns, feed resources and farmers cattle management practices.

3.2.3. Sampling of feed resources and chemical analysis

Quadrants measuring 25 x 25cm and a 500m transect line were used to sample grass species in grazing areas in Ncorha and Gxwalibomvu. Quadrants were placed on 10 random points on every 50m mark on the transect line for five transect points. The grass species within each quadrant were collected and packed in bags. Sampling of browse tree species foliage was done in a 2m radius at every 10m point on the transect line. Crop and crop residues samples were taken from all farmers who had them in storage to make up to 1kg. Commercial feed was collected from Ncorha and Gxwalibomvu custom feeding centres. The samples were bagged up to 1kg separately. All samples were collected during the dry season (mid July 2015) and the wet season (late November 2015).

3.2.4. Nutritional composition data collection

A proximate analysis was carried out, in quadruplicate, using official methods of analysis (AOAC, 2002) to determine the chemical composition of the identified locally available feed resources. Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) were analysed using the filter bag technique of the ANKOM Technology (Van Soest, 1967). *In vitro* dry matter digestibility (IVDMD) was carried out using the daisy incubator method. Total phenol and tannins were determined using Makkar, (2003)'s method. Condensed tannins (CT) were determined following the procedure by Porter et al. (1985).

3.2.5. Statistical analysis

Descriptive statistics were computed using the PROC FREQ procedures of SAS (2016). The effect of socio-demographic profiles and geographical location on herd sizes were analysed using PROC GLM procedure of SAS (2016). The chi-square test was used to determine the association amongst season and geographical location with availability of feed resources (SAS, 2016). A weighted index developed using XLSTAT in Microsoft Excel was used to rank reasons for keeping cattle and importance of feed resources. The effect of type of feed or plant species and season and their interaction on the nutritional composition of feed resources was analysed using PROC GLM procedure of SAS, (2016). The linear model used was: $Y_{ijk} = \mu + F_i + S_j + (FS)_{ij} + \varepsilon_{ijk}$

Where:

Y_{ij} = nutrient content (DM, CP, Fat, Ash, NDF, ADF, ADL, IVDMD, C.T)

μ = overall mean

F_i = effect of feed resource (i = *A. mearnsii*, Lucerne, cultivated grass, natural pasture grass, commercial feed, maize cob, maize stover, maize grain)

S_j = effect of season (j = wet, dry, year 1 and year 2)

$(FS)_{ij}$ = interaction of the ith feed resource and jth season

ε_{ijk} = error associated with main effects and interactions.

Pair-wise comparisons of the least square means were performed using the PDIFF test (SAS, 2016). The significance threshold for all statistical analyses was set at $P < 0.05$.

3.3. Results

3.3.1. Socio-demographic attributes of cattle producers

Sixty percent of the interviewed farmers were over 60 years of age. Male-headed households constituted 60% of the total respondents in both communities. There were slightly more female-headed households in Gxwalibomvu (38%) than Ncorha (32%). The minority (13%) of the respondents in Ncorha had tertiary education compared to those in Gxwalibomvu (>50%) ($P < 0.05$). Almost all (90%) of the respondents in Ncorha had up to primary education compared to 55% of the farmers in Gxwalibomvu. About one third of Ncorha interviewees and more than 50% of Gxwalibomvu interviewees were pensioners. There were more (44%) unemployed respondents from Ncorha than Gxwalibomvu (21%).

3.3.2. Cattle herd size, composition and uses

Ncorha farmers had slightly larger herd sizes than Gxwalibomvu farmers (Table 3.1). Herds in both communities comprised mostly cows and calves ($P < 0.05$) as shown in Table 1. Cattle sales was the major reason for keeping cattle followed by savings and slaughter during ceremonies (Table 3.2).

3.3.3. Cattle feeding management

Natural pastures were the major source of feed for cattle throughout the year. Most of the interviewed farmers (61%) practiced free grazing while the remaining 39% herded their animals. The majority (56%) of the interviewees in Gxwalibomvu did not know the dominant

Table 3.1: Cattle herd compositions of the surveyed areas (Mean ± S.E)

Herd class	Gxwalibomvu	Ncorha
Females (cows and heifers)	3.6 ± 2.80	4.6 ± 2.80
Calves	2.7 ± 0.78	2.8 ± 0.78
Steers	2.4 ± 2.00	4.3 ± 2.00
Bulls	0.9 ± 0.2	0.9 ± 0.2
Total	11.3 ± 1.2	13.7 ± 1.1

Table 3.2: Reasons for keeping cattle on a weighted average ranking index

Reason for Keeping	Ranking Index	Rank
Sales	0.177	1
Savings	0.152	2
Ceremonies	0.147	3
Social status	0.139	4
Milk	0.127	5
Meat	0.0834	6
Lobola	0.0585	7
Manure	0.0576	8
Draught power	0.0395	9

grass species in their natural pasture and 35% of the interviews reported *Panicum maximum* (Guinea grass) to be the most dominant grass species. Almost all (98%) farmers from Gxwalibomvu did not know the dominant browse species in their natural pasture, only 2% identified *Vachellia karroo* (Sweet thorn, previously known as *Acacia karroo*).

Cynodon dactylon (L.) Pres. (Common couch grass) was the dominant grass species in Ncorha. Few respondents (2% and 10%) identified *V. karroo* and *A. mearnsii* (Black wattle) as the most dominant browse species, respectively. The majority (87%) of the participants indicated that grazing material was abundant in the wet season. About 75% of the farmers mentioned that natural pasture quantity and quality was low during the dry season. Only 29% of respondents from both communities used basal cover to evaluate natural pasture condition. Participants in Ncorha and Gxwalibomvu (53%) described natural pasture condition as mediocre, while 23% did not know its condition. Seasonal drought was reported by 54% of the interviewees as the major cause of natural pasture deterioration. Overgrazing and fire were reported to have small impact on the natural pasture condition. The main source of water for cattle were rivers (68%) and dams (53%).

Body condition scores of the animals were determined using a scale on the questionnaire. The herd average body condition score of cattle was 1.5 in both communities during the dry season and 3.45 in the wet season. Nearly 80% of the respondents provided supplements to their cattle during the dry season. Farmers in both communities utilised maize stover and lucerne more than the other supplements (Table 3.3). Participants (26%) in Ncorha supplemented with maize in contrast to 3% of participants in Gxwalibomvu. Farmers in Gxwalibomvu prioritised reproductive animals (i.e. bulls and cows) compared to calves and steers (Table 3.4). Similarly, farmers in Ncorha prioritised only cows and bulls over steers, heifers and calves (Table 3.4).

Table 3.3: Types of supplements used by farmers in Ncorha and Gxwalibomvu

Supplement	Ncorha	Gxwalibomvu
Commercial feed	9%	3%
Maize	26%	3%
Maize stover	60%	70%
Browse legumes	3%	3%
Lucerne	26%	30%

Table 3.4: Herd supplement allocation for farmers in Ncorha and Gxwalibomvu

Animal class	Ncorha	Gxwalibomvu
Calves	58%	61%
Heifers	48%	76%
Steers	20%	76%
Cows	78%	90%
Bulls	75%	93%

3.3.4. Nutritional composition of the locally available feed resources

The interaction of feed type and season had a significant effect on some of the chemical attributes of the feed resources (Table 3.5). Amongst grasses and leguminous feed resources, lucerne hay had the highest crude protein content during the dry and wet seasons followed by *A. mearnsii* ($P < 0.05$; Table 3.5). *Acacia mearnsii* had the highest crude fat content in wet and dry season compared to other feed resources ($P < 0.05$). Lucerne hay harvested in the dry season had the highest ($P < 0.05$) ash content followed by grasses, cultivated hay coming after natural pasture hay. *A. mearnsii* had the least ash content. Cultivated grass hay had the highest ($P < 0.05$) fibre content (NDF and ADF) in both seasons, followed by natural pasture hay. Cultivated hay and *A.*

Table 3.5: Effect of season on nutritional composition (%) of the most common grass and leguminous feed resources.

Sample	*A. mearnsii*		Lucerne hay		Cultivated grass hay		Natural pasture hay	
Season	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**
DM	94.1±0.76^{a}	87.2±0.76^{b}	94.4±0.76^{a}	89.4±0.76^{c}	94.2±0.76^{a}	92.8±0.76^{a}	94.0±0.76^{a}	86.7±0.76^{b}
CP	15.2±0.08^{d}	16.2±0.08^{c}	17.9±0.08^{b}	22.5±0.08^{a}	5.9±0.08^{e}	n.a	4.5±0.08^{f}	3.9±0.08^{g}
Fat	4.9±0.33^{a}	3.0±0.33^{b}	2.5±0.33^{b}	1.3±0.33^{d}	0.6±0.33^{ef}	0.6±0.33^{ed}	1.8±0.33^{c}	1.2±0.33^{f}
Ash	5.3±0.28^{e}	4.6±0.28^{e}	7.6±0.28^{d}	10.2±0.28^{a}	8.6±0.28^{c}	8.5±0.28^{c}	9.6±0.28^{ab}	9.6±0.28^{ab}
NDF	37.1±0.73^{d}	36.1±0.73^{d}	32.9±0.73^{e}	35.3±0.73^{d}	77.2±0.73^{a}	69.6±0.73^{b}	61.3±0.73^{c}	68.1±0.73^{b}
ADF	31.2±0.96^{e}	33.1±0.96^{e}	26.3±0.96^{f}	28.2±0.96^{f}	52.0±0.96^{a}	48.9±0.96^{b}	38.4±0.96^{d}	42.7±0.96^{c}
ADL	15.9±2.19^{ab}	19.0±2.19^{a}	6.0±2.19^{d}	6.5±2.19^{d}	23.0±2.19^{a}	20.7±2.19^{a}	9.9±2.19^{bc}	11.0±2.19^{b}
IVDMD	58.8±0.38^{b}	58.7±0.38^{b}	73.0±0.38^{a}	72.1±0.38^{a}	37.1±0.38^{e}	28.7±0.38^{f}	45.2±0.38^{c}	25.9±0.38^{d}
C. T (g/kg)	77± 0.86	76±0.86	n.a	n.a	n.a	n.a	n.a	n.a

^{a,b,c} Least square mean (± standard error of mean) with different superscripts in a row are different ($P < 0.05$). n.a = not analysed

Table 3.6: Nutritional composition of sampled crop-based feed resources sampled in 2015 (year 1) and 2016 (year 2)

Sample	Commercial ration		Maize cob		Maize grain		Maize stover	
Year	**Year 1**	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**
DM	88.7±0.76^{d}	86.1±0.76^{e}	95.6±0.76^{b}	98.8±0.76^{a}	94.0±0.76^{bc}	73.5±0.76^{h}	96.7±0.76^{ab}	86.4±0.76^{e}
CP	14.3±0.08^{a}	14.3±0.08^{a}	2.13±0.08^{f}	1.96±0.08^{f}	7.14±0.08^{b}	5.86±0.08^{c}	4.92±0.08^{d}	2.98±0.08^{e}
Fat	1.99±0.33^{b}	1.83±0.33^{b}	0.42±0.33^{c}	0.98±0.33^{c}	3.79±0.33^{a}	3.28±0.33^{a}	0.70±0.33^{c}	0.70±0.33^{c}
Ash	8.54±0.28^{b}	7.93±0.28^{c}	1.67±0.28^{e}	1.58±0.28^{e}	1.41±0.28^{e}	0.57±0.28^{f}	33.9±0.28^{a}	6.03±0.28^{d}
NDF	35.3±0.73^{d}	31.8±0.73^{e}	83.6±0.73^{a}	83.5±0.73^{a}	7.49±0.73^{f}	6.94±0.73^{f}	79.0±0.73^{b}	69.6±0.73^{c}
ADF	22.2±0.96^{d}	21.8±0.96^{d}	46.0±0.96^{a}	46.0±0.96^{a}	3.28±0.96^{e}	3.01±0.96^{e}	45.7±0.96^{ab}	42.4±0.96^{c}
ADL	6.49±2.19^{a}	5.85±2.19^{a}	7.20±2.19^{a}	7.19±2.19^{a}	n.a	n.a	4.87±2.19^{a}	4.53±2.19^{a}
IVDMD	77.3±0.38^{a}	76.8±0.38^{a}	39.5±0.38^{c}	32.1±0.38^{d}	n.a	n.a	65.6±0.38^{b}	65.3±0.38^{b}

a,b,c Least square mean (± standard error of mean) with different superscripts in a row are different ($P < 0.05$). n.a = not analysed *mearnsii* had the highest ($P < 0.05$) ADL content followed by natural pasture hay. Except for NDF in the wet season, *Acacia mearnsii* had higher fibre content compared to lucerne in both seasons. Season had no effect on the IVDMD of lucerne hay and *A. mearnsii* which was consistently higher ($P < 0.05$) than grasses, although lucerne had higher ($P < 0.05$) IVDMD than *A. mearnsii*. The dry season reduced the IVDMD of cultivated grass hay and natural pasture hay ($P < 0.05$). Season had no effect on condensed tannins in *A. mearnsii*.

The interaction of year of sampling and feed type had a significant effect on the chemical composition of the sampled feed resources (Table 6). Across the years, commercial ration had the highest crude protein content among the crop-based feed resources and maize cob had the least ($P < 0.05$). Year 2 maize grain and stover had lower ($P < 0.05$) crude protein content than that sampled in year 1. Maize grain had the highest ($P < 0.05$) fat content followed by commercial ration, maize stover and maize cob, in that decreasing order. Ash content of commercial ration, maize grain and maize stover was lower ($P < 0.05$) in the second year of sampling than in the first year. Maize cob had the highest ($P < 0.05$) fibre content (NDF, ADF and ADL) across both years followed by maize stover. Maize stover sampled in year 2 had lower ($P < 0.05$) fibre content (NDF and ADF) than that sampled in year 1. Similarly, commercial ration sampled in year 2 had lower ($P < 0.05$) NDF than that sampled in year 1. Season had no effect on other fibre components of the crop-based ingredients. The commercial ration had the highest ($P < 0.05$) IVDMD followed by maize stover then maize cob.

3.4. Discussion

The surveyed communities are beneficiaries of the NAMC custom feeding program. The primary objective of the programme is to improve market access of communal cattle through weaner value addition (Nyhodo *et al.*, 2014). The NAMC established custom feeding centres where communal farmers may have their weaners managed and finished prior to marketing using subsidised commercial feed comprised mainly of *Glycine max*, straw and maize. Besides consumer concerns about the chemical additives in commercial concentrates (Yiridoe *et al.*, 2005; Napolitano *et al.*, 2010), the initiative might not be sustainable when NAMC withdraws its support (Nyhodo *et al.*, 2014; Marandure *et al.*, 2016) since farmers will not afford the commercial feed. With that at hand, it is imperative to devise sustainable feeding regimes to ensure continuity of the custom feeding programme.

The finding that natural pasture was the main feed resource was expected because natural available feed resources are limited in semi-arid areas. Crop production in semi-arid areas is compromised by a combination of by marginal and erratic rainfall patterns (Mzezewa *et al.*, 2010), high temperatures and poor soils (Mandiringana *et al.*, 2007) which result in poor yields exacerbating the human-livestock food conflict. Farmers have to be empowered to increase crop production through utilization of water harnessing methods as proposed by Hensley *et al.* (2000) and soil fertility improvement through livestock manure. Jari and Fraser (2009) pointed out the importance of integrated crop-livestock systems in the efficient use of resources. The finding that *P. maximum* and *C. dactylon (L.) Pres* were the dominant grass species is attributed to the shallow soils found in the surveyed areas (Cowling & Potts, 2015). The rhizomes of *P. maximum* and *C. dactylon (L.) Press* are short (Ferreira, 2005) which allows them to thrive in shallow soils. Furthermore, grazing by livestock reduces the rejuvenation vigour of the less dominant species (Swanepoel *et al.*, 2008) leaving the more resistant species such as *P. maximum* and *C. dactylon (L.) Pres* to prevail. The observation that most the farmers did not know the species in their grazing lands and how to manage them may be ascribed to limited education and pasture management knowledge. Less than half and about one eighth of the farmers in Gxwalibomvu and Ncorha respectively had tertiary education. Kabirizi *et al.*, (2009) established that farmer's education is of essence when it comes to adopting production techniques and management strategies.

The finding that natural pasture biomass and quality was seasonal agrees with earlier finding by Mapiye *et al.* (2010a) who attributed it to seasonal fluctuations in rainfall and temperature. The intra-annual spatial distribution of rainfall results in a curvilinear relationship with forage availability, forage nutritional composition, cattle average daily gains, body condition scores and herd numbers (Mellink & Martin, 2001; Nyamukanza *et al.*, 2008; Mapiye *et al.*, 2009a). This can also be supported with the results on chemical composition of the feed resources sampled in different seasons from the current study. Due to the nutritional constrain during the dry season, farmers provided supplements to their animals. Farmers could harvest the grasses during the wet season when the nutritional value is at its optimum for use during the dry season. The grasses can be complimented with protein rich browse tree legume species, like *A. mearnsii*, which are abundant in the surveyed areas. The finding that *A. mearnsii* was dominant in the surveyed areas may be associated with their invasive nature.

The finding that *A. mearnsii* and lucerne had higher CP content is attributed to them being legumes. The observed CP levels of these legumes (152 g/kg – 225 g/kg) is above the recommended CP maintenance requirement for steers (60 – 80 g/kg DM, NRC, 2000) and the minimum CP requirement optimum for microbial growth (126 g/kg CP DM, NRC, 2000). This entails that *A. mearnsii* and lucerne are suitable to be used as cattle finisher diets. The observation that *A. mearnsii* and *M. sativa*'s CP content and IVDMD was high and ADF, NDF, ADL was low during the dry season than the wet season contradicts findings by Salem (2005) and Evitayani et al., (2004). The authors recorded higher crude protein content in the leguminous browse during the wet season. The discrepancy could be accredited to differences in environmental conditions. The Eastern Cape Province receives winter snow and late summer rains (ARC, 2016) and the little rains received by sampling time was insufficient for nutrient recuperation. However, the Ncorha community has a dam and irrigates their lucerne. During the wet season, the sprouting grass had higher crude protein content and lower total fibre hence very digestible than during the dry season.

The finding that fat content was generally higher in the wet season is postulated to be attributed by the presence of more essential oils. During the dry season, the volatile compounds of the plants evaporate together with the moisture due to the heat/drying (de Torres *et al.*, 2010). The ash content, a representative of mineral content, of all the sampled feed resources, except maize stover harvested in year 1, is within the normal range and can be manipulated to meet the animal's vitamin and mineral requirements.

The observation that cultivated grass had the highest fibre (NDF, ADF and ADL) content among the pasture based feed resources and maize stover among crop based feed resources could be due to their highly fibrous nature (Devendra & Sevilla, 2002). When coupled with less fibrous feed resources, they can provide the required 300g/kg DM NDF (NRC, 2000) for animal maintenance and growth.

Maize residues (stover) are left in farmers' fields for *in situ* stubble grazing in the surveyed communities. The use of maize stover may be attributed to the fact that maize is the staple food crop (Traub & Jayne, 2006) hence it is cultivated more. Furthermore, Ncorha is a beneficiary of a government-funded communal irrigation scheme hence residing farmers have access to food crops and crop residues (Marandure *et al.*, 2016). The irrigation programme also explains the finding that lucerne (*Medicago sativa*) was the most commonly used legume. Khadda et al., (2015) established that *Medicago sativa* strives in semi-arid ecosystems provided a sufficient water supply is available. The Ncorha community has a dam which can support the irrigation of lucerne. On the other hand, the establishment and maintenance costs involved with lucerne cultivation are exorbitant for the resource-constraint farmers. Moreover, lack of technical knowhow can also restrict the productivity of lucerne (Khadda *et al.*, 2015). Lucerne, together with maize stover, require appropriate handling and storage facilities to minimise nutrient bleaching, maximising its utilisation (Wambugu *et al.*, 2011; Kamanzi & Mapiye, 2012) as a dry season cattle diet.

The finding that the IVDMD of common grass and leguminous feed resource in the wet season is significantly higher than during the dry season could be related to high NDF, ADF and ADL which are in turn related to lignification and defoliation of the pasture throughout the dry season (Stockdale, 1999). The harvesting of pasture grass during the wet season is therefore recommended to harness the quality fodder that can be utilised during the dry season.

Thornless *A. mearnsii* can be harvested with more ease and used as a protein source to compliment the energy rich forages. The finding that *A. mearnsii* leaves contain polyphenolic compounds is consistent with the findings of Dube et al., (2001) when they sampled six common *Vachellia* species in South Africa. The presence of high concentration of tannins in the leaves of *A. mearnsii* may retard growth and reduces feed intake (Makkar, 2003b) limiting its effective utilisation by ruminants. However, tannin concentration can be moderated to beneficial levels of between 20g/kg and 60g/kg through cost effective methods like drying, and ash treatment (Mapiye *et al.*, 2011; Mlambo *et al.*, 2011). The findings of Muchuweti et al., (2006) suggest a significant decrease in tannin concentration when tanniferous feeds are either oven or sun dried. Sun drying is more suitable to communal areas compared to oven drying or ash treatment since it does not have complex procedures. The condensed tannin level of *A. mearnsii* (77g/kg DM) is within moderate range that is beneficial to the ruminant. Studies by Kozloski et al., (2012) reported increased microbial nitrogen entering the duodenum with increasing inclusions up to 60g/kg DM of *Acacia mearnsii* extract on wethers. Max et al., (2007) reported reduced anthelmintic effect on nematode burdens in sheep and goats with increasing inclusions of up to 170g/kg DM of tannin extract. Hence, effective sun drying of *A. mearnsii* can be beneficial to ruminants.

3.5. Conclusion

Natural pasture grass and crop residues were the most locally available feed resources. *Acacia mearnsii*, a legume tree, is a potential protein supplement in the surveyed areas which when complimented with natural pasture grass as energy sources, has the potential to be a low-cost diet for cattle. Lucerne supplemented with cereals and crop residues have the potential of being a valuable finishing diet for cattle in communities with adequate water for irrigation. The development of cost-effective feeding strategies prior to slaughter and/or marketing is of paramount importance in improving off-take rates. Further studies to evaluate the effect of such low-cost diets on growth performance of cattle are therefore, recommended.

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Chapter 4: Growth performance and carcass quality of non-descript crossbred steers fed diets containing *Acacia mearnsii* and *Medicago sativa* as alternative protein sources to *Glycine max*

Abstract

The objective of the current study was to assess the growth performance and carcass quality of crossbred steers fed *Acacia mearnsii* (black wattle) and *Medicago sativa* (lucerne) as alternative protein sources to *Glycine max* (soybean meal). Thirty-six 12-month-old steers were randomly allocated to the three diets (n = 12 per treatment); commercial beef cattle finisher diet (*G. max*-based), *Acacia mearnsii* leaf meal-based diet and *Medicago sativa*-based diets under feedlot conditions for 120 days. The induction mean weight ± standard error of the animal was 158 ± 12.9 kg. The steers fed *A. mearnsii*-based diet had lower (P < 0.05) average daily feed intake (7.84 ± 0.090 kg) and average daily gain (ADG) (0.29 ± 0.041kg) than steers fed *M. sativa*-based and *G. max*-based diets. Steers fed the *A. mearnsii*-based diet, however, had a poorer (P < 0.05) feed conversion ratio (20.50 ± 2.53) than steers fed *M. sativa*- and *G. max*-based diets. Steers fed *M. sativa*-based diet had the highest warm and cold carcass weights followed by those fed the *G. max*-based and *A. mearnsii*-based diets, respectively (P > 0.05). The *A. mearnsii*-based diet had the least (P < 0.05) variable costs consequently the highest (P < 0.05) gross margin (R376.22 ± 279.55) compared to the *M. sativa*-based and *G. max*-based diets. The *G. max*-based and *M. sativa*-based diets had positive effects on growth performance and carcass characteristics of the steers compared to the *A. mearnsii*-based diet but were less economical than the *A. mearnsii*-based diet. *A. mearnsii* leaf meal has the potential to be a low-cost feeding alternative to finish cattle under feedlot conditions.

Keywords: feedlot, feed conversion ratio, *Acacia mearnsii*, low cost diets, alternative feeds

4.1. Introduction

South Africa's beef production industry is dichotomous, with the commercial sector and smallholder sector, which is further divided into emerging and communal farmers (Mkhabela, 2010). The commercial sector and some emerging farmers practice feedlotting in addition to free-ranging on natural or improved pastures. The majority of smallholder farmers rely on natural pasture to raise and finish their animals (Bryson *et al.*, 2002). However, productivity of cattle is affected by the seasonal fluctuations of natural pasture quality and quantity (Muchenje *et al.*, 2008; Mapiye *et al.*, 2011). Natural pasture quality and abundancy is high in the rainy season but the dry season is often characterised by acute shortages and low quality pasture, with crude protein being the most limiting nutrient (Mapiye, 2009). In most cases supplementary feeding during the periods of inadequacy is restricted by the poor financial conditions of communal farmers (Tada *et al.*, 2012).

As an intervention by the government through the National Agriculture Marketing Council (NAMC) has spearheaded the development of custom feeding programmes in communal areas of South Africa to improve animal condition before marketing. In the custom feeding programmes producers send the animals to feed yards where they are managed and finished using subsidized commercial diets prior to marketing (Marandure *et al.*, 2016b). The major concern of the custom feeding programme is its sustainability after the NAMC withdraws feed subsidies (Marandure *et al.*, 2016a). In this regard, development of effective, cheap and readily accessible alternative protein sources for use in beef cattle finisher diets to substitute the expensive soybean/sunflower in commercial diets could be important for the sustenance of the custom feeding programme.

Some communal cattle producers utilise improved forage legume such as lucerne *(Medicago sativa)* as a source of crude protein (Chapter 3). However, expensive agronomic inputs such as seed, fertilisers, herbicides and insecticides are required just like in food crop production (Mccallum *et al.*, 2001). These biocides also present a risk of chemical residues in beef and beef by-products (Paredi *et al.*, 2013). Utilisation of exotic herbaceous browse legumes like *Acaciella angustissima* and *Leucaena spp.* have been evaluated (Hove *et al.*, 2001; Rubanza *et al.*, 2005; McSweeney *et al.*, 2008), but their establishment require high input of seed and fertiliser thus limiting their potential. The utilisation of naturally occurring protein sources such as browse tree legumes in cattle production is, therefore, essential.

Vachellia (formerly known as *Acacia)* species have been used as livestock protein sources because of its availability throughout the year (Barnes *et al.*, 1996). Among these species, *Vachellia karroo* is gaining importance as a leaf meal supplement for ruminants because of its high crude protein and mineral concentrations (Mapiye *et al.*, 2011b; Idamokoro *et al.*, 2016). Thornless *A. mearnsii*, with similar nutritional characteristics, has potential to unlock similar utilisation due to the absence of spines. Although the presence of polyphenolic compounds limits the utilisation of *A. mearnsii* by ruminants (Kozloski *et al.*, 2012), simple detannification processes based on drying can be implemented to reduce the deleterious effects of high tannin levels in the leaf meal (Jawad *et al.*, 2013; Pascariu *et al.*, 2014). Currently, *A. mearnsii* is labelled as one of the dominant woody species exacerbating the problem of bush encroachment on communal rangeland in South Africa (Richardson & Van Wilgen, 2004) . Its utilisation as animal feed might simultaneously reduce bush encroachment and improve rangeland and animal productivity in South Africa.

The effectiveness of forage legumes such as *A. mearnsii* and *M. sativa* in improving growth and carcass characteristics of non-descript crossbred beef cattle under feedlot conditions in South Africa is largely unknown. The objective of the current study was to evaluate growth performance carcass quality of non-descript crossbred steers fed diets containing alternative protein sources (*A. mearnsii* leaf-meal and *M. sativa hay*) to *G. max* (soybean) meal. It was hypothesised that the growth performance and carcass parameters of non-descript crossbred steers finished on diets containing *A. mearnsii* leaf meal, *M. sativa* hay were similar to those fed diets containing *G. max* meal.

4.2. Materials and methods

4.2.1. Study site

The study was conducted at the Agricultural Research Council feedlot pens, Queenstown, South Africa, GPS -32° 926722 S, 26° 931491 E. It lies in the false thornveld of the Eastern Cape characterised by partially dystrophic and partially eutrophic savannah populated by sparse stands of *Vachellia karroo*

(Moyo *et al.*, 2009). It is approximately 1070m above sea level and receives a mean annual rainfall of 500mm received mostly during summer months, October to April.

4.2.2. Preparation of feeds

4.2.2.1. *Acacia mearnsii*-based diet

Acacia mearnsii was harvested at Ikhephu Feedlot, Elliot, South Africa between November 2015 and February 2016 by lopping small branches with a petrol-powered hand chain saw. The cut branches were stacked (1- 1.5m high) on 5 x 3m black plastic sheets. The leaves were sun dried for 3 days. The dried leaves were shaken off the branches. The leaves were then collected from the plastic sheets and bagged. The leaves were mixed with crushed yellow maize and pasture hay in a 500kg capacity Rumax mixer for 20 minutes. Thereafter, the ration was bagged, labelled and transported to ARC feedlot pens in Queenstown to be stored in a cool, dry and well-ventilated warehouse. The diet was formulated using Large Ruminant Nutrition System (LRNS v 1.0.33, 2015). The ingredient inclusion levels are shown in Table 4.1 and the chemical composition of the diet is shown in Table 4.2.

4.2.2.2. *Medicago sativa*-based diet

The *M. sativa*-based diet was prepared at Ikhephu Feedlot, Elliot, South Africa. The *Medicago sativa*, yellow maize and maize stover were sought from distributers and farmers around Elliot. The ingredients were hammer-milled separately using a Drotsky M16 hammer mill and then mixed in a 500kg capacity Rumax mixer for 20 minutes. Thereafter, the ration was bagged and labelled. The diet was formulated using Large Ruminant Nutrition System (LRNS v 1.0.33, 2015). The ingredient inclusion levels are shown in Table 4.1 and the chemical composition of the diet is shown in Table 4.2.

4.2.2.3. *Glycine max*-based diet (control)

The *G. max*-based treatment was a commercial diet (complete cattle finisher) sought from Driehoek Feeds, Free State through the NAMC.

4.2.3. Treatments and feeding management

The trial was conducted with the ethical approval of Stellenbosch University Research Ethics Board (SU-ACUD15-00067). Thirty-six 12-month old crossbred steers with a mean weight of 157.9 ± 31.37 kg were paired in matching weights before being randomly allocated to the three dietary treatments. The steers were acquired from smallholder farmers from Elliot, Indwe and Bholotwa in the Eastern Cape Province. All the steers were drenched for internal parasites using Valbazen Ultra. Furthermore, steers were ear-tagged for easy identification.

Table 4.1: Ingredient inclusion levels of experimental diet

	***A. mearnsii*-based diet**	***M. sativa*-based diet**
Ingredient	**Inclusion level (%)**	
Acacia mearnsii leaf	47.91	-
Pasture hay	31.87	-
Maize	20.22	33.33
Medicago sativa hay	-	46.67
Maize stover	-	20.00

4.2.4. Management of steers

A pair of steers on the same treatment were kept in a pen measuring 10 x 5 m. Steers were paired due to inadequate pen space. The steers were allowed 21 days for dietary adaptation prior to the 100-day feeding trial commencing from August 2016 to November 2016. Steers in one pen shared feeding and water troughs. Animals were fed twice a day, at 0900 h and 1500 h. Feed offered and refusals for each pen were weighed and recorded. Feed intake for the pair was calculated as the difference between the feed allocated and refusals. Steers had *ad libitum* access to feed and clean fresh tap water throughout the experiment. Steers were weighed and dipped with a commercial acaricide every 15 days. The steers were also palpated and scored using a 5-point scale (1-emaciated and 5-obese) to estimate body condition score (BCS) every 15 days when weighing the animals.

4.2.5. Chemical composition of the experimental diets

A fraction of the diets and refusals was collected every day and put in respective bags. A sample was taken from the bags every seven days for chemical analysis. The *A. mearnsii*-based, *M. sativa-based* and *G. max*-based rations and residues were assessed for DM, CP, crude fat according to Association of Official Analytical Chemists (AOAC, 2003) methods. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Van Soest *et al.* (1991). The tannins were extracted and total phenolics determined using Makkar, (2003) method. Condensed tannins were determined following the procedure by Porter et al. (1985).

4.2.6. Slaughter procedures

A day prior to slaughter, the steers were weighed and transported to East London abattoir, (185 km south-east of Queenstown). Steers were kept overnight in a holding area deprived of feed but with *ad libitum* access to clean fresh water. Animal slaughter and dressing were done humanely, following the commercial slaughter procedures of East London Abattoir. The captive bolt method was used to stun the animals. Carcasses were electrically stimulated, using a voltage of 300 V, a frequency of 50 Hz, a current of 5 A in 40–45 s at a pulse of 12/s, to control the effect of rapid chilling on cold shortening of muscles. The dressed carcass comprised the body after removing the skin, the head at the occipitoatlantal joint, the fore-feet at the carpal–metacarpal joint, the hind feet at the tarsal–metatarsal joint and the viscera. Warm carcass weight, conformation and carcass classification grades were recorded. The carcasses were classified according to the South African carcass classification system (SAMIC, 2006). The dressing percentage was calculated as warm carcass weight expressed as a percentage of the live weight.

4.2.7. Economic analysis

The gross margin analysis was employed to determine the cost effectiveness of the finisher diets. The gross margin was obtained by subtracting the total variable costs from total income. Total variable costs for each treatment were calculated as costs directly related to production of the rations such as labour, fuel, transport and feed. The variable costs were calculated per kilogram of feed and multiplied by the total feed intake of each animal.

4.2.8. Statistical analyses

The effect of diet on final weight, ADG and feed conversion ratio (FCR) were analysed using PROC MIXED procedure of SAS (SAS, 2016) with diet set as the main effect, pen and initial weight as the random effects. Pen was used as the experimental unit. The effect of diet on carcass characteristics was analysed using the PROC MIXED procedure of SAS (SAS, 2016) with diet set as the main effect and final weight and animal as random factors. In this model, animal was used as an experimental unit. The model used was: $Y_{ijkl} = \mu + D_i + P_j + (DP)_{ij} + (DW)_{ik} + (DPW)_{ijk} + \varepsilon_{ijkl}$

Where:

Y_{ijkl} = final weight, ADG, FCR and gross margin

μ = overall mean,

D_i = effect of diet (i= *A. mearnsii*-based, *M. sativa*-based and *G. max*-based)

P_j = effect of pen (j = A, B, C….R),

$(DP)_{ij}$ = interaction i^{th} diet and j^{th} pen

ε_{ijk} = residual error.

Carcass fat, conformation and grade were displayed in a contingency table. Treatment means were generated and separated using the LSMEANS and PDIFF options, respectively. The significance threshold for all statistical analyses was set at $P < 0.05$.

4.3. Results

4.3.1. Nutritional composition of the experimental diets

The nutritional composition of the experimental diets is shown in Table 4.2. The *A. mearnsii*-based diet had the least moisture content, followed by the *G. max*-based then the *M. sativa*-based. The *G. max*-based diet had the highest crude protein (13.3%) and ash content (12%) compared to the *M. sativa*-based (11.9%; 6.6%) and *A. mearnsii*-based diets (10.54%; 4.49%). The *A. mearnsii*-based diet had the higher fibre content (NDF, ADF and ADL) followed by the *M. sativa*-based then the *G. max*-based diet. The *G. max*-based diet had no tannins present while the *M. sativa*-based had 2g/kg DM and *A. mearnsii*-based had 28g/kg DM. All the experimental diets had a high crude protein digestibility (>97.5%), although *A. mearnsii*-based had the lowest digestibility.

Table 4.2: Nutritional composition (%) of the experimental diets

	***A. mearnsii*-based**	***M. sativa*-based**	***G. max*-based**	**± SD**
Dry matter	93.26	91.02	91.14	1.75
Crude protein	10.54	11.93	13.33	1.37
Ash	4.49	6.75	12.00	8.47
Neutral detergent fibre	46.26	42.36	30.79	7.70
Acid detergent fibre	27.86	26.92	14.48	6.97
Acid detergent lignin	10.30	6.94	4.66	3.10
Condensed Tannins (g/kg DM)	28	2	-	13
Crude protein digestibility	97.62	97.99	98.02	0.182

4.3.2. Growth performance

The effect of the interaction of time on feed and diet is shown in Figure 4.1. Feed intake increased with time on feed with steers fed *G. max*-based and *M. sativa*-based diets consuming significantly more (P < 0.05) feed than those fed *A. mearnsii*-based diet. Diet had a significant effect on final weight, ADG and feed conversion ratio (P<0.05). *Glycine max*-fed steers had the highest slaughter weights, ADG (Table 4.3) and BCS (Figure 4.2) followed by *M. sativa*- and *A. mearnsii*-fed steers, respectively (P < 0.05). Steers fed *A. mearnsii*-based diet had higher (P < 0.05) FCR than those fed *G. max*-based and *M. sativa*-based diets.

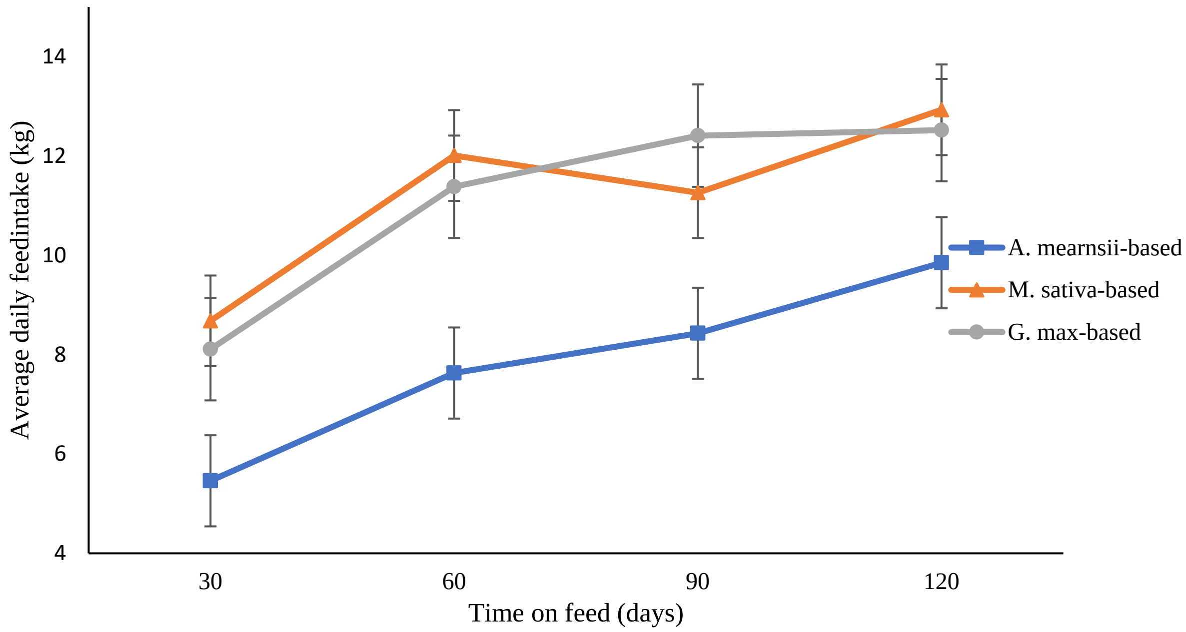

Figure 4.1: Effect of time on feed on average daily feed intake of crossbreed steers fed A. mearnsii-, M. sativa- and G. max-based diets

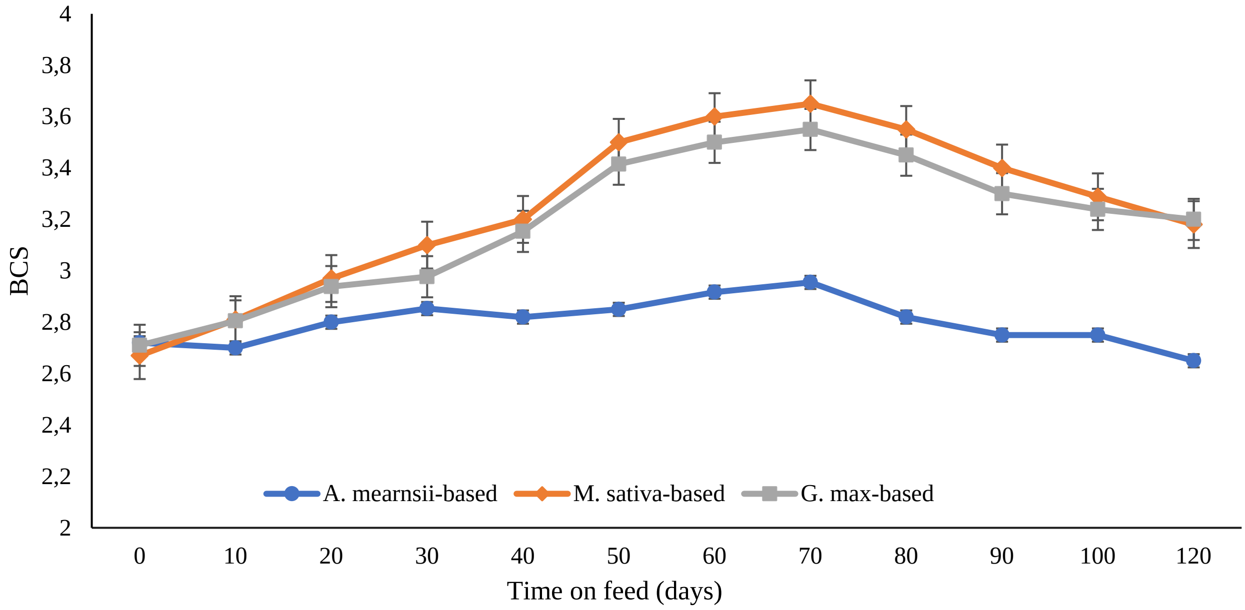

Figure 4.2: Body condition scores of crossbreed steers fed *A. mearnsii*-, *M. sativa*- and *G. max*-based diets

Table 4.3: Effect of diet on growth performance of crossbreed steers fed A. mearnsii-based, M. sativa-based and G. max-based diets

Carcass characteristic	**Dietary treatment**		
	***A. mearnsii*-based**	***M. sativa*-based**	***G. max*-based**
Initial weight	166.7 ± 9.14	153.9 ± 9.14	153.0 ± 9.14
Final weight (kg)	201.8[b] ± 9.74	248.0[a] ± 9.74	248.9[a] ± 9.74
ADFI (kg)	7.84[b] ± 0.090	11.22[a] ± 0.089	11.10[a] ± 0.089
ADG (kg)	0.29[b] ± 0.041	0.78[a] ± 0.041	0.80[a] ± 0.041
FCR	20.50[a] ± 2.53	5.41[b] ± 2.53	5.74[b] ± 2.53

[ab] Values within a row with a different superscript are significantly different at $P < 0.05$

4.3.3. Carcass characteristics

Diet had no effect ($P > 0.05$) on the warm and cold carcass weights (Table 4.4). However, dressing percentage of *A. mearnsii*-fed carcasses was higher ($P < 0.05$) than that of *G. max*- and *M. sativa*-fed steers. The cooler loss, fat thickness, pH and carcass temperature at 45 minutes and 24 hours after slaughter were not affected by diet ($P > 0.05$). About 58% *A. mearnsii*-fed steers had a fat score of 0, while 50% of steers on *M. sativa*-based and *G. max*-based steers had carcasses with a fat score of 1 (Table 4.5). Eighty percent of all the steers had a conformation score of 2. Half of the steers fed *A. mearnsii*-based diet were graded A0 while 50% and 42% of steers fed *M. sativa*-based and G. max-based, respectively, were graded A1 (Table 4.5).

Table 4.4: Effect of diet on carcass characteristics of mixed breed steers fed A. mearnsii-based, M. sativa-based and G. max-based diets

Parameter	**Dietary treatment**		
	***A. mearnsii*-based**	***M. sativa*-based**	***G. max*-based**
Warm carcass weight (kg)	119.4 ± 7.69	124.6 ± 7.69	124.4 ± 7.69
Cold carcass weight (kg)	115.7 ± 7.47	120.9 ± 7.47	120.7 ± 7.47
Dressing percentage	57.69^{a} ± 2.82	48.76^{b} ± 2.82	48.78^{b} ± 2.82
Cooler loss percentage	3.01 ± 0.009	2.99 ± 0.0093	3.01 ± 0.009
Carcass pH_{45min}	6.78 ± 0.042	6.83 ± 0.042	6.90 ± 0.042
Carcass $temperature_{45min}$ (°C)	32.66 ± 0.30	32.91 ± 0.29	33.03 ± 0.29
Carcass $pH_{24\ hrs}$	6.21 ± 0.035	6.26 ± 0.045	6.29 ± 0.040
Carcass $temperature_{24\ hrs}$ (°C)	3.94 ± 0.25	4.56 ± 0.31	4.86 ± 0.28

[ab] Values within a row with a different superscript are significantly different at $P < 0.05$

Table 4.5: Carcass characterises of crossbreed fed A. mearnsii-based, M. sativa-based and G. max-based diets

Characteristic	Class	Diet		
		***A. mearnsii*-based**	***M. sativa*-based**	***G. max*-based**
Fat	0 - No visible fat on carcass	19.4%	8.3%	8.3%
	1 - Very lean carcass	11.1%	16.7%	16.7%
	2 – Lean carcass	2.8%	8.3%	8.3%
Conformation	2 – Flat carcass	27.8%	27.8	25.0%
	3 – Medium carcass	5.6%	5.6	8.3%
Age	A0 -Most tender with no incisors	16.7%	8.3%	8.3%
	A1 – Most tender with one incisor	11.1%	16.7%	13.9%
	A2 – Most tender with two incisors	2.8%	5.6%	8.3%
	AB0 – Tender with no incisors	2.8%	-	-
	AB2 – Tender with two incisors	-	2.8%	2.8%

4.3.4. Economic analyses

The cost of raw materials of the *G. max*-based diet was the highest followed by *M. sativa*-based and *A. mearnsii*-based diet, respectively (P < 0.05; Table 6). The *G. max*-based and *M. sativa*-based carcasses had a significantly higher (P < 0.05) total income compared to the *A. mearnsii*-based carcasses (P < 0.05; Table 6). On the contrary, steers fed *A. mearnsii*-based diet had the highest profit margin followed by those fed *M. sativa*-based diet and *G. max*-based steers, respectively (P < 0.05; Table 6).

Table 4.6: Gross margin analysis for finishing steers with A. mearnsii-based, M. sativa-based and G. max-based diets

Parameter	Diet		
	***A. mearnsii*-based**	***M. sativa*-based**	***G. max*-based**
Feed ingredients[1] (R)	248.01^{c} ± 105.61	1473.69^{b} ± 105.61	2360.71^{a} ± 105.61
Labour[2] (R)	471.51^{a} ± 23.98	168.90^{b} ± 23.98	0
Fuel[3] (R)	233.47 ± 11.37	0	0
Total Income (R)	1329.21^{b} ± 318.30	1853.74^{a} ± 318.30	2282.59^{a} ± 318.30
Gross margin (R)	376.22 ^{a} ± 279.55	211.15^{b} ± 279.55	-78.12^{c} ± 279.55

^{abc} Values with different superscript within the same raw are significantly different at $P < 0.05$

[1] Values indicate the cost of bought-in feed ingredients or complete feed

[2] Values indicate the cost of human resources during the feed processing

[3] Value indicates the cost of fuel used during harvesting of *A. mearnsii* leaf meal

4.4. Discussion

The lower ADFI recorded for the *A. mearnsii*-based diet could be attributed to the astringent taste of tannins (Landau *et al.*, 2000; Makkar, 2003b) which in turn reduce palatability of the diet (Kumar & Singh, 1984). The depressed feed intake could, to a lesser extent, also be attributed to the rumen fill effect (Kumar & Singh, 1984). Condensed tannins impede digestibility in the rumen (Makkar, 2003b) and digesta in the rumen is maintained at a constant level. Any decrease in digestibility reduces rate of passage (Landau *et al.*, 2000) inducing the rumen fill effect.

The observation that the ADG of steers fed *A. mearnsii*-based diet was lower could be attributed to the low voluntary dry matter intake which results in low nutrient intake. Low metabolisable energy (ME) and CP intake retard growth because of limited availability of nutrients (Owens *et al.*, 1995; Castro Bulle *et al.*, 2007). Low nutrient intake could also be evidenced by the poor FCR of steers fed *A. mearnsii*-based diet. Due to lower ADG steers on *A. mearnsii*-based diet had lower final weight compared to their counterparts. Furthermore, the low ADG in *A. mearnsii*-based steers could be attributed to low ruminal carbohydrate digestion (Frutos *et al.*, 2004; MacAdam & Villalba, 2015). The breakdown of complex structural carbohydrates to simple sugars by extracellular microbial enzymes is essential to produce pyruvate which is converted to volatile fatty acids (McDonald *et al.*, 2011). Condensed tannins (CT) bind with microbial enzymes, forming condensed tannin-enzyme complexes which inactivate extracellular enzymes (Barry *et al.*, 1984). Furthermore, CT interfere with the adhesion of microbial bacteria to forage cell walls, inhibiting the digestion of complex sugars (Barry & Manley, 1986). The CT-enzyme complexes pass through to the small intestine, where they are dissociated. The carbohydrases in the small intestine, α-amylase for instance, cannot break down the complex carbohydrates despite the dissociation (Huntington *et al.*, 2006). Overall, CT limit energy supply to the animal and thus retard growth and limit daily gain.

Steers fed *M. sativa*-based diet and *G. max*-based had a higher ADG because higher proportion of cereals. Cereal based diets have high proportions of rapidly fermentable carbohydrates (RFC). One of the main products of RFC fermentation in the rumen is butyrate, from which energy for live weight gain is derived (Moran, 2005). Furthermore, high proportions of butyric acid in the rumen stimulate propagation of papillae on the rumen wall (McDonald *et al.*, 2011), increasing surface area for absorption of volatile fatty acids (VFAs).

Dressing percentage of steers fed *A. mearnsii*-based diet was higher and these findings concur with Mapiye *et al.* (2010) who recorded higher (>50%) dressing percentage for steers supplemented with *V.*

karroo leaf meal. MacAdam & Villalba, (2015) mentioned the effect of condensed tannins in feedlot performance and revealed higher dressing percentages (>57%). This finding could be attributed to the weight of the fifth quarter and the non-integral parts of the carcass (Macitelli *et al.*, 2005). Animals fed concentrate based diets tend to develop larger organs to cater for higher metabolism and deposit more internal fat (Ferreira *et al.*, 2000).

The finding that all steers were lean (fat score < 2) is chiefly related to age of the steers at the time of slaughter. Growing animals deposit less subcutaneous fat compared to mature animals (Lawrence *et al.*, 2012). Trivially, the low-fat score of the carcasses could be due to the breed. Although the steers in this current study were not genotyped, they were largely crossbreeds between indigenous Sanga (*Bos tauraus Africunus*) and Zebu (*Bos indicts*) with European breeds (*Bos tauraus breeds*).

The finding that *A. mearnsii*-based diet had the highest gross margin could be explained by lower variable costs. Similar to the findings of the current study, Chakoma *et al.* (2016) found that concentrate based diets are more expensive than supplemented natural pasture based fed resources. The cost of feed or supplement influences the choice of feed used by farmers (Devendra & Sevilla, 2002) since feed constitutes the biggest input share by value in any animal production system (Nyhodo *et al.*, 2014). Utilisation of a low-cost *A. mearnsii* leaf meal as a finishing diet could be a lucrative option for resource-limited communal farmers.

4.5. Conclusion

The *G. max*- and *M. sativa*-based diets had positive effects on growth and carcass characteristics compared to the *A. mearnsii*-based diet but were less economical than the *A. mearnsii*-based diet. It was concluded that *A. mearnsii*-based diets can be a cost-effective feed resource for resource-limited farmers. However, the contribution of *A. mearnsii*-based diets to the meat quality and fatty acid composition of beef is relatively unknown. It is recommended that further studies to investigate the effect of A. mearnsii-based diet on meat quality and fatty acid profiles of steers are undertaken.

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Chapter 5: Meat quality and fatty acid composition of steers fed diets containing *Acacia mearnsii* leaves and *Medicago sativa* as alternative protein sources to *Glycine max*

Abstract

The objective of the current study was to assess the meat quality of steers fed *Acacia mearnsii* (Black wattle) and *Medicago sativa* (lucerne) as alternative protein sources to *Glycine max* (soybean) meal. Thirty-six yearling steers were randomly allocated to the three dietary treatments; commercial beef cattle finisher diet (*G. max*-based, control), *Acacia mearnsii* leaf meal-based diet and *Medicago sativa*-based diet under feedlot conditions. The steers were slaughtered after 120 days on feed and the *m. longissimus thoracis* (LT) was sampled for meat quality and fatty acid (FA) composition analyses. Diet had no effect ($P > 0.05$) on meat colour (L*, a*, b*, chroma and hue), pH, temperature, drip loss, shear force, crude protein and fat. Meat from steers finished on *A. mearnsii*-based diets had higher ($P \leq 0.05$) moisture and ash content than meat from those finished on *G. max*-based and *M. sativa*-based diets. Meat from steers fed *A. mearnsii*-based diets had the highest cooking losses followed by those fed *M. sativa*- and *G. max*-based diets, respectively ($P \leq 0.05$). Meat from steers fed the *M. sativa*-based diet had higher ($P \leq 0.05$) proportions of individual and total SFA and (n-) 3 PUFA and lower ($P \leq 0.05$) proportions of linoleic acid and total n6 PUFA than *G. max* and *A. mearnsii*- based diets. It was concluded that steers fed *A. mearnsii*- and *M. sativa*-based diets produced comparable beef quality and fatty acid composition to those fed the *G. max*-based diet.

Keywords: colour, tenderness, *Acacia mearnsii*, alternative protein, fatty acids

5.1. Introduction

The demand for animal-based protein is escalating with the swelling human population in most African countries (Gede *et al.*, 2016). Due to population increase, the beef production industry is confronted by multifaceted market needs (Soji *et al.*, 2015). The increase in the standards of living have made beef consumers develop heterogeneous consumption patterns and inconsistent preferences (Soji *et al.*, 2015). Furthermore, affluent consumers are becoming increasingly cautious about the quality of meat they purchase (Feldmann & Hamm, 2015) in terms of nutritional value, origin, healthfulness, production process and safety (García-Torres *et al.*, 2016). The beef production industry ought to evolve to produce and offer meat quality of choice to the consumer (Marandure *et al.*, 2016a).

Schaake et al. (1993) recommended the inclusion of forage in finishing diets of steers for lean and healthful beef. Natural pasture, the main source of forage and browse, is cost-efficient, particularly for the smallholder beef producers compared to feeding grain-based diets (Bahta & Baker, 2015). Several authors claimed that pasture-raised beef is rich in omega (n-) 3 fatty acids (FA) and antioxidants, vitamin E and carotenoids in particular, among other beneficial effects pertaining to human health (Pouzo *et al.*, 2016). Studies by Muchenje *et al.* (2008) and Mapiye *et al.* (2010b) demonstrated that feeding forage based diets yield comparable beef quality and better fatty acid profiles than grain-based diets. Raising cattle on pasture could minify the risk of “diseases of poverty” (Mapiye *et al.*, 2015) since the greater population in developing countries could afford to eat healthy beef. However, raising cattle solely on pasture is a slower process, compared to finishing on concentrate diets (Ruechel, 2012). On the contrary, producing conventional animal feeds under current changing climate is not only becoming expensive, but intensification of the cultivation of crops is often unsustainable (Ellis *et al.*, 2013). To minimise the cost of feeds while producing comparable beef yield and quality within a reasonable time frame, forages or browse based feeds could to be included in the beef cattle finishing diets (Raidan *et al.*, 2016). That would benefit smallholder farmers in the semi-arid areas who rely on their cattle for food, income and social security (Chapter 3).

Using natural pasture based diets in finishing beef cattle may, to an extent, reduce the cost of feeds and positively impact animal production (Idamokoro *et al.*, 2016). Some farmers in the smallholder areas, for example in the Eastern Cape Province in South Africa have the capacity to cultivate *Medicago sativa* (lucerne) through established irrigation schemes. However, large parts of natural pastures have been invaded by *Vachellia karroo* (sweet thorn) and *Acacia mearnsii* (black wattle) (Chapter 3; Marandure *et al.*, 2016). There is limited if any literature on the feeding value of *A. mearnsii* based diets, especially its effects on the beef quality and fatty acid composition. The objective of this study was, therefore, to assess meat quality and fatty acid composition of feedlot steers fed diets containing *A. mearnsii* and *M. sativa* as alternative protein sources to *Glycine max* (soybean) meal.

5.2. Materials and methods

5.2.1. Animal management

The feeding trial was conducted at Agricultural Research Council (ARC) feedlot in Queenstown in the Eastern Cape Province of South Africa (GPS 31°55’36.62” S, 25°55’54.22” E). The feeding trial was carried out under the Animal Ethical clearance approved by Stellenbosch University Research Ethics Board (SU-ACUD15-00067). The detailed description of the study site was given in section 4.2. Details of dietary treatments, feeding and animal management were described in sections 4.2.3 and 4.2.4, respectively. Rangeland biomass and nutritional analyses of the feed constituents (rangeland, hay, *A. mearnsii*) and diets were described in Sections 4.2.5 and 4.2.6, respectively.

Slaughter procedures and carcass measurements were described in Section 4.2.9. The *m. longissimus thoracis* (LT) of the left side was sampled between the 11th and 13th rib 24 hrs after slaughter. The LT muscles were vacuum packed in a cooler box with ice during transportation from East London abattoir to Stellenbosch University for meat quality analyses.

5.2.2. Meat quality measurements

5.2.2.1. pH and drip loss measurement

The pH-value of the LT was measured using a Crison PH25 pH meter at 24 hours after slaughter. Two pieces of meat measuring approximately 15 x 15 x 30 mm were sliced from the LT steak for drip loss measurement in a way that the fibres ran across the longer axis of the sample. The samples were suspended on wire hooks in plastic sample bags is such a way that the sample did not touch any side or the bottom of the bag. The suspended samples were stored in a cold room at 4°C for 24 h. Drip loss was calculated as the percentage difference between the initial and final weight of the sample.

5.2.2.2. Determination of meat colour

Muscle colour was measured using a spectro-guide D65/10° (daylight illumination, aperture opening) 45°/0° colorimeter (BYK Gardner GmbH, Gerestried, Germany) 24 hours *post-mortem*. Colour measurements were done on the side of the LT across the grain. A portion of approximately 30g of the LT was cut and left to bloom for at least 30 minutes at chiller temperatures (4°C) before recording. The following CIE (1976) colour coordinates were measured: lightness (L^*), redness (a^*) and yellowness (b^*) from three locations on the cut surface of individual steaks. Chroma and hue angle (colour saturation) were calculated as the square root of the sum of a^{*2} and b^{*2} and the arc-tan of b^*/a^*.

5.2.2.3. Determination of chemical composition of meat samples

The moisture content was determined according to AOAC official method 934.01. Samples of 2.5 g of homogenized meat were placed in dry, marked, crucibles, the weights of which had been recorded. The samples were allowed to dry at 100 - 105°C for a minimum of 24 hours. They were subsequently removed from the oven and placed in a desiccator to cool. Once completely cool the crucibles and dried samples were weighed. The moisture content of the samples was calculated as the difference between the sample weight before and after drying.

The moisture-free samples were used for the determination of the ash content. The crucibles were placed in a furnace at 500°C for a minimum of six hours. They were then allowed to cool, first in the furnace and finally in a desiccator, before weighing. The ash content was determined as the remaining mass of the sample after incineration and expressed as a percentage of the original wet weight of the sample (AOAC, 2002 method 942.05).

The fat content was determined on 5g of homogenized sample using a 1:2 chloroform/methanol solution for fat extraction. A rapid solvent extraction method was used, as described in Lee, Trevino and

Chaiyawat (1996).The defatted sample obtained as a by-product of the fat determination was used to determine the protein content of the sample. This was done using the LECO combustion or Dumas method. The defatted samples were dried completely and ground to a fine powder, 0.5g of which was weighed off into LECO™ foil cups and analysed for nitrogen content. This nitrogen content was multiplied by a factor of 6.25 in order to obtain the protein content of the sample, which was subsequently converted to a value per gram wet meat (AOAC, 2002, method 992.15). The LECO was recalibrated after every ten test samples using an EDTA calibration sample (LECO Corporation, St Joseph, MI, USA).

5.2.2.4. Determination of cooking loss and Warner-Bratzler shear force

Two steaks measuring approximately 30 mm were cut from the LT and weighed. The steaks were placed in thin-walled marked plastic bags and placed in a 70°C water bath with the opening well above the surface of the water. The steaks were cooked for approximately 60 minutes then removed. The accumulated water was poured out and the steak were chilled to 4°C then weighed and the weight recorded as final weight. The steaks were stored in the chiller at 4°C for shear force measurements. Cooking loss was calculated as the difference between the before and after cooking weight expressed as a percentage of the weight before cooking.

The Warner Bratzler shear force test (WBSF) was used to analyse the instrumental shear force of the cooked meat samples (Honikel, 1998). Shear force readings were taken 72 h after refrigerated storage (2-4°C) of the cooked meat samples (from the LT of the LTL). Three adjacent 1 cm x 1 cm rectangular meat strips were cut parallel to the muscle fibre direction from the centre of the samples. The meat strips were cut to obtain a total of six rectangular cubes with a length of 2 cm per cube. An Instron Universal Testing Machine (Instron UTM, Model 2519-107) attached with a Warner-Bratzler (WB) fitting, a 1 mm thick triangular (V-notch) blade with a semi-circular cutting edge (radius of 0.508 mm), was used (Voisey, 1976). The maximum shear force values required to shear a sample of cooked muscle perpendicular to the muscle fibre longitudinal axis (at a crosshead speed of 200 mm/min) was recorded for each sample in Newton (N) and the value was converted to kilograms (kg).

5.2.3. Determination of fatty acid composition

Two grams of each sample were homogenized for 30 seconds in 50 ml chloroform: methanol (2:1; v/v) solution containing 0.01% butylated hydroxytoluene (BHT) as an antioxidant by use of a polytron mixer (WiggenHauser, D-500 Homogenizer). Heptadecanoic acid (C17:0) was used as an internal standard to enable quantification of the individual fatty acids in the original muscle sample. A sub-sample was taken from the extracted fats and transmethylated for 2 h at 70 °C with a methanol: sulphuric acid (19:1; v/v) solution. The sub-sample was cooled to room temperature after which the resulting fatty acid methyl esters (FAME) were extracted with the use of water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen. Fifty microliters (ul) of hexane was added to the dried sample of which 1 µl was injected.

The FAME were analysed by gas–liquid chromatography (Varian Model 3300 equipped with a flame ionization detector) using a 60 m BPX70 capillary column of 0.25 mm internal diameter (SGE International Pty Ltd, 7 Argent Place, Ringwood, Victoria 3134, Australia). The hydrogen gas flow rate was 25 ml/min and the hydrogen carrier gas flow rate was 2–4 ml/min. Temperature programming was linear at 3.4 °C/min with the following temperature settings: initial temperature of 60 °C; final temperature of 160 °C. Injector temperature was 220 °C and detector temperature was 260 °C. The run time was ≈45 min. The FAME in the total lipids of each sample (mg/g sample) were identified by comparing the retention times with those of a standard FAME mixture (Supelco™ 37 Component FAME Mix, 10 mg/ml in CH2Cl2, Catalogue Number 47885-U. Supelco™, North Harrison Road, Bellefonte, PA 16823-0048, USA). The individual fatty acids were expressed as a proportion of the total fatty acids.

5.2.4. Statistical analysis

The effect of diet on meat quality attributes and fatty acid composition of beef were analysed using PROC MIXED procedure of SAS (SAS, 2016) with diet set as the main effect and animal as the random effect. The model used was: $Y_{ij} = \mu + D_i + \varepsilon_{ij}$

Where: Y_{ij} = meat quality attribute and fatty acid composition

μ = overall mean

D_i = effect of i^{th} diet (i = *A. mearnsii*, *M. sativa*, *G. max*)

ε_{ij} = residual error associated to the effects and the interaction.

Treatment means were generated and separated using the LSMEANS and PDIFF options, respectively. The significance threshold for all statistical analyses was set at $P \leq 0.05$.

5.3. Results

5.3.1. Meat physical attributes

The effect of diet on meat quality attributes is shown in Table 5.1 and 5.2. Diet had no effect ($P > 0.05$) on meat temperature, pH_u, drip loss, color parameters and shear force (tenderness). Diet had an effect on cooking loss ($P \leq 0.05$). The meat from steers fed the *A. mearnsii*-based diets had higher ($P \leq 0.05$) cooking losses than meat from steers fed the *G. max*-based diet. Cooking losses of meat from steers fed *M. sativa*-based diet were, however, not different ($P > 0.05$) from that of steers fed *G. max*- and *A. mearnsii*-based diets.

5.3.2. Meat chemical attributes

Diet had no effect ($P > 0.05$) on the meat chemical composition, except for ash and moisture content. Meat from steers fed the *A. mearnsii*-based diet had higher ($P \leq 0.05$) moisture content than meat from steers fed *G. max*-based diet. The *M. sativa*- and *G. max*-based LT had higher ($P \leq 0.05$) ash content than *A. mearnsii*-based LT.

Table 5.1: Physical meat quality attributes for LT muscle from steers fed *A. mearnsii*-, *M. sativa*- and *G. max*-based diets

Characteristic	**Diet**			**s.e.m**
	A. mearnsii	***M. sativa***	***G. max***	
Muscle pH_{24}	5.44	5.46	5.41	0.20
Muscle $temperature_{24}$ (°C)	13.80	13.86	13.55	0.20
Drip loss (%)	2.50	2.10	2.76	0.35
a*	8.65	8.48	8.44	0.26
b*	11.01	10.47	10.70	0.20
L*	39.36	39.31	39.38	0.59
Chroma	14.06	13.53	13.69	0.28
Hue	52.24	51.44	52.03	0.73
Cooking loss (%)	44.33a	42.33ab	41.80b	0.90
Shear force (kg)	11.75	12.14	11.60	0.39

[ab] Values with a different superscript are significantly different $P < 0.05$.

Table 4: Chemical composition of meat from LT from steers fed *A. mearnsii*, *M. sativa*- and *G. max*-based diets.

Parameter (%)	**Diet**			**s.e.m**
	***A. mearnsii*-based**	***M. sativa*-based**	***G. max*-based**	
Moisture	77.17^{a}	76.65^{ab}	76.40^{b}	0.26
CP	20.37	20.80	21.18	0.36
Fat	1.76	1.99	1.89	0.20
Ash	1.11^{b}	1.69^{ab}	1.32^{a}	0.16

^{ab} Values with a different superscript are significantly different P<0.05.

5.3.3. Fatty acid composition

The *G. max*-based diet had the highest proportions of myristic acid (C14:0) followed by *M. sativa*-based diet and *A. mearnsii*-based diet, in that order ($P \leq 0.05$). *A. mearnsii*-based diet had the highest proportions of pentadecylic acid (C15:0) followed by *M. sativa*-based diet and *G. max*-based diet, respectively ($P \leq 0.05$). Meat from steers fed the *M. sativa* diet had lower ($P \leq 0.05$) palmitic acid proportions than meat from those fed *A. mearnsii*- and the *G. max*-based diets. Stearic (C18:0), arachidic (C20:0) and heneicosylic (C21:0) acids and total SFA proportions were higher ($P \leq 0.05$) in *M. sativa*-based diet than in *A. mearnsii*-based and *G. max*-based diets, with no significant difference between them ($P > 0.05$). Behenic acid (C22:0) proportions were highest in *M. sativa*-based diet, followed by that in *G. max*-based diet and lastly *A. mearnsii*-based diet ($P \leq 0.05$). The proportions of lignoceric acid (C24:0) were higher ($P \leq 0.05$) in *M. sativa*-based than *A. mearnsii*-based diet with G-max diet having similar ($P > 0.05$) proportions to both diets.

The *A. mearnsii*-based had higher ($P \leq 0.05$) proportions of palmitoleic acid (C16:1) than *M. sativa*-based and *G. max*-based diets with no significant ($P > 0.05$) different between them. The proportions of oleic acid (C18:1n9c) and total UFA were not influenced by diet ($P > 0.05$). *A. mearnsii*-based diet had the highest proportions of linoleic acid (C18:2n6) followed by *G. max*-based diet and lastly *M. sativa*-based diet ($P \leq 0.05$). The proportions of γ-linolenic (C18:3n6) were higher ($P \leq 0.05$) in *M. sativa*-based diet than in *G. max*-based and *A. mearnsii*-based diets with no significant difference found between them. Diet had no effect ($P > 0.05$) on the proportion of eicosadienoic (C20:2n6) and arachidonic (C20:4n6) acids. The proportions of docosadienoic acid were higher ($P \leq 0.05$) in *M. sativa*-based diet than *G. max*-based diets but both diets had similar ($P > 0.05$) proportions to that of the *A. mearnsii*-based diet. Total (n-) 6 PUFA was greater ($P \leq 0.05$) in *A. mearnsii*-based diet than in *M. sativa*-based diets, and *G. max*-based diet had similar ($P > 0.05$) values to both diets. The α-linolenic acid (C18:3n3) proportions were not affected by diet ($P > 0.05$). The proportions of eicosatrienoic acid (C20:3n3) and total (n-) 3 PUFA were higher ($P \leq 0.05$) in *M. sativa*-based diets than in *A. mearnsii*-based and *G. max*-based diets with no significant ($P > 0.05$) difference found between them.

Table 5.3: Fatty acid composition (%) of LTL from steers fed *A. mearnsii*-, *M. sativa*- and *G. max*-based diets

Fatty acid	Diet			
	***A. mearnsii*-based**	***M. sativa*-based**	***G. max*-based**	**s.e.m**
Total FA (mg/g)	17.28	20.31	19.46	2.98
C14:0	0.13[c]	0.39[b]	0.83[a]	0.160
C15:0	0.90[a]	0.53[b]	0.25[c]	0.051
C16:0	10.73[a]	7.25[b]	9.63[a]	0.510
C18:0	18.72[b]	21.51[a]	19.24[b]	0.406
C20:0	1.48[b]	2.19[a]	1.54[b]	0.100
C21:0	4.70[b]	5.63[a]	4.49[b]	0.281
C22:0	1.14[c]	1.66[a]	1.34[b]	0.051
C24:0	3.93[b]	4.98[a]	4.61[ab]	0.241
∑ SFA	41.72[b]	44.14[a]	41.93[b]	0.513
C16:1	1.00[a]	0.83[b]	0.75[b]	0.046
C18:1n9c	29.4	29.12	30.67	0.991
∑ MUFA	30.40	29.94	31.42	0.999
C18:2n6	13.26[a]	8.63[c]	11.43[b]	0.495
C18:3n6	1.12b	1.87[a]	1.35[b]	0.116
C20:2n6	1.01	1.11	1.07	0.062
C20:4n6	6.86	7.24	7.33	0.329
C22:2n6	1.44[ab]	1.65[a]	1.35[b]	0.074
∑ n6	23.70[a]	20.49[b]	22.52[ab]	0.729
C18:3n3	1.06	1.20	1.12	0.058
C20:3n3	3.47[b]	4.56[a]	3.52[b]	0.276
∑ n3	4.53[b]	5.75[a]	4.64[b]	0.311
∑ PUFA	28.23	26.25	27.16	0.882

5.4. Discussion

The lack of dietary influence on meat pH_u and temperature at 24 hours could reflect that diets had similar energy levels. Although the energy levels of the diets in the current study was not determined, it is predicted that diets with sufficient energy levels make the meat accumulate glycogen deposits that lead to a slow pH decline (Priolo *et al.*, 2001a). Although the *A. mearnsii*-based diet was low in starch, its fibrous nature might have compensated for the energy deficiency (Immonen *et al.*, 2000; Priolo *et al.*, 2001b). The pH_u at 24 hours conforms with the normal meat pH_u of 5.5 ± 0.3 (Lawrie & Ledward, 2006) as well as other previous studies similar to the present study (Scollan *et al.*, 2014; Karaca *et al.*, 2016).

The current study has showed drip loss values that were relatively higher than those from similar studies of Muchenje *et al.* (2008); Mapiye *et al.* (2010a); Frylinck *et al.* (2013) and Frylinck *et al.* (2015). The difference could be attributed to the age of animals at the time of slaughter. Ninety two percent of the steers in the current study were young animals with no permanent incisors (Chapter 4). Younger animals have small muscle fibre diameter which contributes negatively to water-holding capacity (Lawrie & Ledward, 2006). In young animals, the protein connections of the cytoskeleton are intact and this transfers shrinkage in the length of the myofibrils to shrinkage in the whole muscle hence the more exudate compared to older animals (Hughes *et al.*, 2014).

While meat lightness (*L**) values from the current study were within the range of values of previous studies (Mapiye *et al.*, 2010b; Ngambu *et al.*, 2013), redness (*a**) and yellowness (*b**) were lower than those in the above-mentioned studies. The discrepancy could be owing to the fact that the animals in the above mentioned studies were raised solely on pasture compared to those in the current study which were finished with pasture-based diets containing grains. Frylinck *et al.* (2013) claimed that beef from animal raised entirely on pasture appears redder than that from animals in confinement due to the differences in muscle myoglobin concentration owing to the activity prior to slaughter compared to animals finished under feedlot conditions (French *et al.*, 2000). Although the redness and yellowness values were slightly lower than those found in a breed wide study they were within the normal range of *a** 8 to 11 and b* 6 to- 9 (Modika *et al.*, 2015).

The reasons for the difference in the cooking losses of muscle from the *A. mearnsii*-based diet steers and *G. max-based* diet steers could be related the moisture content. The cooking losses results from this study contradict the findings of Hedrick *et al.* (1983); Bruce & Ball, (1990); Bruce *et al.* (2004) and Mapiye *et al.*, (2010b) who reported higher cooking losses from steers fed concentrate based diets compared to those fed forage based diets. Muscles with higher drip loss ought to have lower moisture content since the mechanisms for water retention are similar (Lawrie & Ledward, 2006). The contradictory findings could be related to the rate of pH decline post mortem, which was, however not measured in the current study. Offer *et al* (1989) reported higher water holding capacity values for steaks with rapid pH decline post mortem. This observation could also be due the osmotic pressure of the myofibrils and extracellular space (Hughes *et al.*, 2014). The contradictory findings may be attributed to tannins since they have the ability to avoid the loss of membrane integrity and protein cross-links by inhibiting/or reducing the rate of oxidation in red meat (Gómez-Cortés *et al.*, 2018).

The lack of dietary influence on the muscle tenderness could be attributed to the similarity in the fatness and pH in the meat. Tenderness is mostly affected by the marbling and subcutaneous fat (Frylinck *et al.*, 2015) among other that include management practises during the trial, slaughter procedures, post slaughter handling, pH, WHC, temperature, age and breed (French *et al.*, 2000; Muchenje *et al.*, 2009) which were similar across the treatments in the current study. The tenderness values in the current study are higher than the recommended range of between 4 and 6kg (Geesink *et al.*, 2011). The differences in ash content of the meat could be due to the inorganic content of diets (Chapter 4). It is postulated the higher ash content in *G. max*-based and *M. sativa*-based diets contributed to the high ash content of the meat.

The finding that *M. sativa*-based diet had higher proportions of individual and total SFA is presumed to be due to the bio-hydrogenation of unprotected PUFA in the former diet. The diet had higher proportions of maize and lucerne both being linoleic and α-linolenic acid sources respectively (Burgde, 2018). However, the SFA values are within the recommended range for safe human consumption (FAO - WHO, 2010). The finding that beef fed *A. mearnsii*-based diet had higher linoleic acid and total n-6 PUFA could be ascribed to the effect of secondary plant metabolites, condensed tannins in particular on PUFA bio-hydrogenation. Condensed tannins in the *A. mearnsii*-based diet could have inhibited lipolysis and/ or bio-hydrogenation in the rumen (Morales & Ungerfeld, 2015; Vahmani *et al.*, 2015). Condensed tannins interact with polymers of protein and carbohydrates to form complexes which directly interact with bacterial cell membranes, inhibiting the action of rumen bio-hydrogenation (Costa *et al.*, 2018). Tannins are also thought to lower protozoan populations in the rumen (Yonjalli *et al.*, 2018), contributing to inhibition of lipolysis and /or bio-hydrogenation (Buccioni *et al.*, 2015). The finding that beef from *M. sativa*-based diet had moderate n-6 PUFA and higher n-3 PUFA than other diets could associated with the high PUFA proportions in *A. mearnsii* (*n*-3 PUFA), natural pasture hay (n-3 PUFA) and maize (n-6 PUFA) hay and in the diet. Grass fed beef is characterised by elevated n-3 PUFA (MacKintosh *et al.*, 2017). The proportions of omega-3 and omega-6 fatty acids was lower in the current study than previous studies (Kitessa *et al.*, 2014) although they were in the recommended ranges of between 250 and 500mg per day (Yonjalli *et al.*, 2018). Omega-6 and n-3 PUFA, long chain PUFA are essential in human nutrition for reduction in skin diseases, asthma, atherosclerosis and rheumatoid arthritis, irritable bowel syndrome and muscular degeneration (Mcafee *et al.*, 2010; Abedi & Sahari, 2014).

5.5. Conclusion

Finishing cattle in a feedlot with *A. mearnsii*- and *M. sativa*-based diets produced beef of comparable quality and fatty acid composition to that from steers finished with *G. Max*-based diet. It is essential, however, to determine the optimum inclusion level of *A. mearnsii*- and *M. sativa* for the best meat quality.

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Chapter 6: General discussion, conclusions and recommendations

6.1. General discussion

As the urban-based population increases in most African countries, cattle producers face increasing demand of beef and beef products (Thornton, 2010). The more the population becomes cosmopolitan and urbanised, the more beef consumers increasingly become conscious of the quality of beef they purchase, precisely, its origin, nutritional profile and whether it has been produced sustainably (Marandure *et al.*, 2016). To livestock farmers, such challenges avail necessity for the active integration of the whole value chain to address the rapidly changing consumer expectations amid the changing climate and the increasing feed prices. Furthermore, there is a prevailing challenge of protein being the most limiting nutrient in cattle production on rangeland within the tropics (Mapiye *et al.*, 2010). Moreover, seasonal protein availability hinders cattle from meeting their protein requirements for growth and maintenance, especially during the dry season, compromising cattle production efficiency (Boone & Wang, 2007)

The broad objective of the current study was to assess beef production and quality of steers fed diets formulated using locally available protein sources in communal areas of Eastern Cape, South Africa under feedlot conditions. The main hypothesis was that beef production and quality of non-descript crossbred steers fed *A. mearnsii*-based and *M. sativa*-based diets was similar to that of steers fed a *G. max*-based diet under feedlot conditions.

The hypothesis tested in Chapter 3 was that the locally available feed resources and their nutritional composition in the studied communities (i.e, Ncorha and Gxwalibomvu) in the Eastern Cape Province were similar. Smallholder farmers in the study areas had livestock-based livelihoods, keeping non-descript crossbred cattle the most. Overall, cattle productivity was low because of lack of feed resources, poor breeding and marketing management as reported previously by Musemwa *et al.*, 2008. Feed availability varied with season, following the rainfall patterns. The rangelands in the surveyed areas were invaded by *A. mearnsii*. Farmers in Ncorha cultivated fodder crops like *M. sativa* and *Z. mays* because there was a communal irrigation scheme in their community. Samples of the feed resources mentioned by farmers were collected and analysed for nutritional composition. Among pasture-based feed resources, *A. mearnsii* and *M. sativa* hay had the highest CP content. Cultivated pasture hay had the highest NDF, ADF and ADL content among other natural pasture-based feed ingredients. Among the crop-based feed resources, *Z. mays* grain had the highest CP and fat contents compared to the other feed resources. Farmers also utilised crop residues, maize stover in particular, to supplement their animals. Overall, *M. sativa* and *A. mearnsii* emerged as potential protein sources while *Z. mays* grain, stover and grass hay emerged as promising energy sources. It was therefore, important to formulate cattle finisher diets using these feed resources and evaluate their effects on beef production and quality.

In Chapter 4, a feeding trial was conducted to test the hypothesis that growth performance and carcass characteristics of steers fed *A. mearnsii*- and *M. sativa*-based is comparable to those fed *G. max*-based diet under feedlot conditions. The ADFI, ADG, warm and cold carcass weight and FCR of steers fed the *A. mearnsii*-based diet was lower than that of steers fed *M. sativa*-based and *G. max*-based diets. The *A. mearnsii*-based diet, however, had the higher dressing percentage and gross margin compared to the *M. sativa*-based and *G. max*-based diet. The poor performance from the *A. mearnsii*-based steers was mainly attributed to the low feed intake related high fibre and tannin contents in the diet (Chingala *et al.*, 2018). On the contrary, steers fed *M. sativa*-based and *G. max*-based diets performed better because of the higher DMI.

The hypothesis tested in Chapter 5 was that feeding steers diets containing *A. mearnsii* and *M. sativa* produce comparable meat quality and fatty acid composition with those fed the *G. max* diet. Beef from steers fed *A. mearnsii*-based diet had the highest moisture content and cooking losses. High moisture and cooking losses is postulated to be related to the tannin content in the *A. mearnsii*-based diet due to the ability of tannins to avoid the loss of membrane integrity and protein cross-links by inhibiting or reducing the rate of oxidation in red meat. Diet, however, had no effect on meat colour, chroma, hue, pH, temperature, drip loss, shear force, crude protein and fat content. Meat from steers fed the *M. sativa*-based diet had higher proportions of individual and total SFA and *n*- 3 PUFA. SFA are associated with diseases of lifestyle to include diabetes mellitus, cardiovascular complications and obesity while *n*-3 PUFA are linked to the functionality of the nervous and immune systems (Hall *et al.*, 2016). Beef from steers fed *M. sativa*-based diet had lower proportions of linoleic acid and total n-6 PUFA than *G. max* and *A. mearnsii*- based diets. Moreover, *M. sativa*-based diet produced beef of similar yield and quality to that of steers fed *G. max*-based diets. Smallholder farmers, especially those that had access to irrigation facilities were recommended to use *M. sativa*-based as a protein source when formulating beef cattle finisher diets. Inasmuch as raw materials for formulating *A. mearnsii*-based diets were naturally occurring and relatively abundant in the Eastern Cape, the animal performance of steers fed such diet was poor and farmers' return on investment was, however, high. Further studies are critical to determine the optimum inclusion levels of the *A. mearnsii*-based to improve beef production and quality.

6.2. Conclusions

Steers finished on *A. mearnsii*-based diet had lower feedlot performance, greater gross margins, better n-3 PUFA profile and comparable meat quality to those finished on *M. sativa*- and *G. max*-based diets. The *M. sativa*-based diet had better potential to be used as alternative feeding resources for finishing cattle in a conventional feedlot system than the *A. mearnsii*-based diet. It is important to determine the critical inclusion levels of *A. mearnsii* required to improve beef production and quality.

6.3. Recommendations

Communal farmers with access to irrigation facilities together with emerging farmers with moderate resources can be recommended to use *M. sativa* as protein source when formulating beef cattle finisher diets. Resource-constrained communal beef farmers can be advised to consider utilizing *Acacia mearnsii* to formulate *A. mearnsii*-based diets. In that regard, research to determine the optimum inclusion levels of *A. mearnsii* required to improve beef production and quality should be prioritised. The *A. mearnsii* is abundant in semi-arid areas of EC hence and can be harvest easily at a low-cost. Farmers are also encouraged to use natural pasture hay and crop residues, with small amounts of grain, as energy sources for their bespoke cattle rations.

Aspects that require further research include the following:

1. Characterise the phenolic profile *A. mearnsii* leaves and seeds.
2. Evaluating the optimum inclusion levels of ingredients *A. mearnsii*-based and *M. sativa*-based and diets for improved feed intake, worm loads, growth performance, beef production meat quality and shelf life.

Evaluating the effect of formulating a cattle diet with a combination of *M. sativa* and *A. mearnsii* on feed intake, growth performance, carcass and meat quality.

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