THE POTENTIAL OF *ACACIA KARROO* LEAF MEAL AS A PROTEIN SUPPLEMENT FOR FATTENING GOATS

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Abstract

Acacia karroo is one of the most widespread and abundant indigenous tree legume species in Southern Africa. The tree possesses positive attributes such as high growth rates, drought tolerance, adaptation to acidic infertile soils and resistance to large temperature variations. In the recent past, *A. karroo* was deemed to be a severe encroacher, which adversely affected land utilisation and rangeland productivity. Research attention has been diverted from its riddance as a weed to its utilisation as an animal feed. Widespread adoption of feeding strategies based on *A. karroo* was mainly impeded by the presence of thorns and tannins. The objective of the study was to determine the effects of *A. karroo* leaf meal as a supplement on the growth performance feed intake, feed conversion ratio and body condition score of boar goats. Sixteen 3-month-old Boer goats were kept at the University of Namibia, Neudamm Campus farm. At the beginning of the experiment the goats had a mean body weight of 18.52 kg ± 0. 743 kg (mean ± S.E.) and a mean body condition score of (BCS) of 3.31 ± 0.176 (mean ± S.E.). From birth until weaning the kids were kept on natural pastures with their mothers. The goats were housed in an open sided barn for a period of 60 days, and were fed 600 g/head/day of pellets and Lucerne covering their maintenance and growth needs. For the purpose of the experiment, the goats were randomly divided into four treatment groups of four goats each. The goats were fed on *A. karroo* leaf meal at different levels 0%, 10%, 20% and 25% respectively. The effect of *A. karroo* supplement on growth performance (ADG), voluntary feed intake (VFI), feed conversion ratio (FCR) and body condition score on Boer goats was determined. There was a significant effect (P<0.05) of the *A. karroo* supplement on the VFI (average= 1.026kg ± 0.1954kg (mean ± S.E.)) and FCR (average FCR= 7.892). There was a significant effect ($P<0.05$) of *A. karroo* supplement on the ADG (average ADG =0.130kg ± 0.078kg (mean ± S.E.)) and BSC (average BCS = 4.94 ± 0.213 (mean ± S.E.)). The research demonstrated that *Acacia karoo* leaf meal can substitute protein sources in goat fattening meal up to an inclusion rate of 25%.

Key words: Body condition score, Feed intake, Feed convention ratio, Browse, Bush encroachment.

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List of Abbreviations

A. karroo =	*Acacia karroo*
VFI =	Voluntary Feed Intake
ADG =	Average Daily Gain
ANOVA =	Analysis of Variance
AOAC =	Association of Official Analytical Chemists
CF =	Crude Fiber
CP =	Crude Protein
CRD =	Completely Randomized Design
CRBD =	Completely Randomized Block Design
DAAD =	The German Academic Exchange Service
FCR =	Feed Conversion Ratio
GDP =	Gross Domestic Products
LSD =	Least Significant Difference
MAWF =	Ministry of Agriculture Water and Forestry
ME =	Metabolizable Energy
SFA=	Total saturated fatty acids
MUFA=	Total monounsaturated fatty acids
PUFA=	Total polyunsaturated fatty acids
VFI =	Voluntary Feed Intake

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Dedication

This piece of work is dedicated to my late father, Mr E. Masiku (1958-1997) who was always immersed in fantasy about my success though death came ahead of his revelations through my success in university education.

Declaration

I, Elvin Masiku, hereby declare that this study is a true reflection of my own research, and that this work, or part thereof has not been submitted for a degree in any other institution of higher education.

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CHAPTER 1

1.0. INTRODUCTION

1.1. Orientation of the study

It has been reflected time and again that livestock in Namibia is an important and integral component of agriculture. Agriculture in Namibia contributes around 5% of the national Gross Domestic Product. Not only does the subsector provide the much-needed animal protein for the ever-growing human population, but it also offers employment opportunities for millions of rural and urban dwellers involved in some form of livestock production and marketing (Mushendami, Biwa, & Gaomab II, 2008).

Considering goats in particular, they have a great role in the economy of farming community of Namibia. Namibia's lamb and goat meat (chevon) is well known for its taste, tenderness and wholesome goodness. The major advantage of chevon is its lower fat content compared to other types of red meat (Park et al., 1991). Namibia has 1.8 million goats, well known for their good conformation and tasty meat (FAOSTAT, 2013). A total of 200 000 goats are exported annually to South Africa. The Boer goat is the most popular breed in Namibia. Sale of goats and goat products (meat, skin and milk) by smallholder farming communities is the major source of cash for purchase of clothes, grains and other essential household commodities (MAWF, 1999).

Goats have the ability to adapt to all climatic conditions and are important from an ecological perspective in controlling bush encroachment. Bush encroachment constitutes a major management problem in savannas (Mahanjana & Cronje, 2000).

Persistent invasion of the grass sward by the bush component is caused by various factors, including low fire frequency, under-utilisation of the bush component, and overgrazing of the herbaceous component, which together tip competitive interactions in favour of encroachment by woody species (Smit *et al*., 1999). Goats can effectively control sprouts and regrowth following mechanical control (Du Toit, 1972; Strang, 1974; Trollope, 1974; Trollope *et al*., 1989).

Communal goat production is among the activities used for quick and easy income for communal households. The advantage of goats in low income households is that they are both grazers and browsers and therefore, can effectively utilize a wide range of feed resources with minimal supplementation. There are a number of constraints facing smallholder goat production. Underfeeding has been said to be the major source of problems such as diseases, poor growth and reproduction. Browsable plants have been observed to be a good source of feed, particularly protein, for goats in resource poor areas. Besides being a source of protein, brown species such as *acacia* species contain some polyphenolic compounds with an acaricidal effect on disease causing pathogens in the gastrointestinal tract such as gastrointestinal parasites (Xhomfulana, Mapiye, Chimonyo, & Marufu, 2009). *Acacia karroo* is among plant species which is abundant in most communal rangelands and is preferred by goats for browsing. This plant species is easily accessible by farmers and can be prepared and fed as leaf meal (Mapiye *et al.*, 2009). *Acacia karroo* contains up to 230g/kg CP and can be considered as a cheap source of proteins in communal goat and beef production (Mapiye *et al*., 2009).

Additional protein supplementation (Hoste *et al*., 2005; Hoste, Torres-Acosta, & Aguilar-Caballero, 2008) primarily through the use of protein sources such as *A.*

karroo leaf meal (Mapiye *et al.,* 2009) in ruminant nutrition, improves average body weight gain and hence body condition scores (Arsenos *et al*., 2009). An improved body weight leads to heavier carcasses, thus improving the quality and quantity of meat produced (Arsenos *et al*., 2009). Feeding on *A. karroo* leaf meal has been reported to improve nutritional status, growth performance and carcass traits in cattle (Mapiye *et al.,* 2009).

Excess body fat deposition in meat producing animals is now of concern to both producers and consumers. The latter consideration is important because results of many human studies have related high dietary fat intake to the incidence of cardiovascular diseases and cancer (Lichtenstein, 1999). Due to increasing public demand for low fat and low cholesterol products, interest in manipulating the lipid composition of goat meat via dietary means has become important (Sacks, 2002).

1.2. Statement of the problem

Approximately 2% of meat consumed in the world originates from goats (FAOSTA, 2005). However, it must be noted that goat meat may not be traded as other major meats and it is mostly consumed locally (Solaiman, 2005). Recent advances in animal nutrition have shown that the essential fatty acid profile in meat can be altered through feeding. Thus through the adoption of appropriate feeding strategies, meat can become a functional food. Feeds from plants that contain tannins produce leaner carcasses and therefore, leaner meat (Purchase & Keogh, 1984). In developing countries, most legumes used for animal feeding such as *Leucaena leucocephala*, cow peas and *Acacias* are high in tannins, although abundantly available; they are only used to a limited extent for livestock. The emphasis has been on researching anti-nutritional effects of such feeds and the impact on animal performance. However, the effects of tannins on goat's weight, body condition score and feed intake are not extensively known. Therefore, the present study aimed at determining whether ingestion of tannins rich *A. karroo* would affect the growth performance of Boer goats.

1.3. General Objective

The study was conducted to determine the effect of tanniferous *Acacia karroo* leaf meal level of supplementation on growth performance, feed intake and body condition score of Boer goats.

1.4. Specific objective

a. To evaluate the nutritional composition of tanniferous *Acacia karroo* leaf meal.
b. To determine the effect of tanniferous *Acacia karroo* leaf meal supplementation on feed intake.
c. To determine the effect of tanniferous *Acacia karroo* leaf meal on live weight of Boer goats.
d. To determine the effect of tanniferous *Acacia karroo* leaf meal supplementation on body condition score of Boer goats.

1.5. Hypothesis of the study

a. Tanniferous *Acacia karroo* leaf meal has no potential chemical attributes for goat feeding.
b. Tanniferous *Acacia karoo* leaf meal level of supplementation has no effect on feed intake.

c. Tanniferous *Acacia karoo* leaf meal level of supplementation has no effect on live weight.

d. Tanniferous *Acacia karoo* leaf meal level of supplementation has no effect on body condition score of Boer goats.

1.6. Significance of the study

Plants species like tanniferous A. *karroo* are known to inhabit rangelands and cause bush encroachment. They can be harvested and made available to animals such goats and be utilized as a feed supplement. Harvesting of tanniferous *Acacia karroo* will not only benefit animals but will also restore rangelands to better conditions. Goats play an important economic, nutritional and socio-cultural role in the livelihoods of poor rural households in many developing countries. These livestock have a high socio-economic value and are important to those (often landless) people who do not own cattle, or sheep. Small ruminant production activities are particularly important to women, who often own and manage them and control cash from sales. The resulting income is often used to support education of children.

1.7. Limitation of the study

Seasonal variation in the nutrient value of tanniferous *A.karroo* leaves was most likely to cause variation in the results of the research. The research was therefore, timed by delaying the start because the tanniferous *A. karroo* plants shed their leaves in winter season and start shooting up later on in early spring.

CHAPTER 2

2.0. LITERATURE REVIEW

2.1. Introduction

Goats are important livestock species in developing countries. Goats are hardy and well-adapted to harsh climates. Due to their grazing habits and physiological characteristics, they are able to browse on plants that would normally not be eaten by other livestock species. Thus, the presence of goats in mixed species grazing systems can lead to a more efficient use of the natural resource base and add flexibility to the management of livestock. This last characteristic is especially desirable in fragile environments.

Goat production constitutes an important subsystem of animal production, especially in semi-arid and arid areas (Simela, 2005). Productivity indicators such as sales and home slaughter reveal that goat productivity in smallholder areas is low. This could be due to negative perceptions of chevon by consumers (Webb, Casey, & Simela, 2005). The majority of consumers do not accept chevon in their day-to-day consumption because they perceive it as smelly (Simela, 2005). South African urbanites associate chevon with traditional and religious ceremonies rather than with daily consumption (Simela et al., 2008; Rumosa-Gwaze, Chimonyo, & Dzama, 2009).

Diet has been shown to be one of the main factors influencing carcass yield and qualities in many livestock species (Wood *et al*., 2008), specifically in goats (Warmington & Kirton, 1990; Webb *et al.,* 2005). Feed accounts for the highest single cost of the majority of livestock meat production operations. Goat meat production requires a high quality and balanced diet of mainly proteins. Conventional feeds are expensive and are out of the reach of resource poor farmers. Therefore, profitable goat meat production can only be achieved by optimizing the use of high quality forage and browse instead of more expensive concentrate feeds (Matthew & Jean-Marie, 2002). Browse trees such as *A. karroo* are gaining importance as a protein supplement for grazing ruminants because they are widespread and abundantly available during the dry season (Mokoboki, Ndlovu, Ngambi, Malatje, & Nikolovav, 2005).

2.2. Overview of Agriculture in Namibia

The majority of the people in Africa at large and Namibia in particular acquire their livelihood directly or indirectly from agriculture. Agriculture accounted for about 30 percent on average of the gross domestic product (GDP) for Africa as a whole during 1990 to 1997 (Odada, et al 2002). Despite the fact that most African governments have affirmed agriculture as the basic engine to foster economic growth, it is unfortunate that those pronouncements often lack clear economic policy support or guidance. A review of the agricultural sector during the last decade revealed that the region has been facing perpetual staple food deficit, and that most African states are net staple food importers. This affects the trade balance and the overall balance of payments in most African states adversely. It also deprives most of the states the scarce foreign exchange which could be better spent on the provision of essential services such as health and education (Mushendami, Biwa, & Gaomab II, 2008).

These problems which are experienced by most African states are also pertinent to Namibia.

Namibia is characterised by a dualistic agricultural sector, where a strong commercial sector exists along with a sector comprised of households in freehold or non-freehold areas, (Pholololo 2001). This dualistic character of the sector has been inherited from the apartheid regime, where the minority of the population obtained most of the land, and with the assistance of the state, turned it into viable commercial land (Moorsom, 1985; Elkan et al, 1992; Kirsten and Van Zyl, 1998; Pholololo, 2001). The minority farmers were then given subsidies for settlement, wells, dams, breeding stock and loans (Mushendami, Biwa, & Gaomab II, 2008). Extensive stock farming has been the most dominant activity, and beef production, the major product in the North. Karakul sheep farming was the second most important agricultural product and the major activity in the South. The Karakul is well known for its world class pelts, and is marketed in industrialised countries, while beef is primarily marketed in South Africa and the European Union. It should also be pointed out that almost two-thirds of the agricultural output is accounted for by commercial agriculture, which is over whelming cattle farming.

Of great concern however, is the fact that the share of the agricultural sector to GDP in Namibia has averaged at 11.7 percent for the period 1990 to 1997 (Mushendami, Biwa, & Gaomab II, 2008). This is lower than the average for the Sub-Saharan Africa (SSA), which stood at an average of 30.0 percent during the corresponding period (Odada et al 2002). Moreover, the share of the agricultural sector in Namibia has deteriorated from 6.9 percent in 1999 to 5.4 percent in 2003 (Mushendami, Biwa,

& Gaomab II, 2008). According to Odada, 2002, the deteriorating share of the agricultural sector could be ascribed to the expansion of other sectors such as mining, and services, while the low share of agriculture as a percentage of GDP could be explained by climatic and soil conditions, which are less suitable for agricultural production.

At Independence, the Namibian Government accorded special attention to the development of the agricultural sector. In this regard a number of policy interventions and programmes were embarked upon in order to enhance the output of the sector. These initiatives include the Affirmative Action Loan Scheme (AALS), the National Agricultural Credit Programme (NACP), the Green Scheme, and a ban on export of live animals to South Africa (Mushendami, Biwa, & Gaomab II, 2008).

According to Mushendami, Biwa, & Gaomab II (2008), the agricultural sector sustains about 70 percent of the Namibian population. The sector is also a major earner of foreign exchange for the economy. Accordingly, the agricultural sector accounted for 11.5 percent of the country's total foreign exchange earnings during 2004. Furthermore, the agricultural sector contributed 39 percent to the country's total maize requirements, 12 percent to the domestic consumption of wheat and 100 percent of total consumption of beef, mutton and millet in 2004. Agriculture continues to supports other sectors such as transport, manufacturing, plastic packaging. For example in 2004, agriculture contributed about 2 percent to the total manufacturing output of Namibia (Mushendami, Biwa, & Gaomab II, 2008).

Against this back ground, the importance of the agricultural sector within the Namibian economy, cannot therefore, be overemphasised. The agricultural sector remains critical to the overall objectives of increasing the output of the economy as well as the alleviation of poverty.

The agricultural sector in Namibia can be categorised into two main areas namely, livestock farming and crop farming. Livestock farming constitutes a significant portion of the Namibian agricultural output (Mushendami, Biwa, & Gaomab II, 2008). According to the BON report for 2004, agriculture contributed about 70 percent of the total output of the sector in 1995 before easing to only 59 percent in 2004. Crop farming which accounted for only 8 percent of the total output of the sector in 1995, more than doubled, reaching 17 percent in 2004. Despite, the observed significant growth of crop farming, livestock farming continues to dominate the total agricultural output.

Johnson & Mellor (1961) offer five ways in which the agricultural sector contributes to the overall economic growth: Meeting the food demands of a wealthy and growing urban population; increased agriculture exports as a means of earning foreign exchange; providing labour for the expanding sectors of the economy; providing capital for investment in the growing industrial sectors of the economy, and increased cash incomes in the rural sector which serves to increase demand for the products of the industrial sector.

2.2.1. Livestock Farming

Livestock farming in Namibia comprises cattle, sheep, goats and pigs. In terms of output, beef production is the major livestock farming activity in Namibia followed by mutton/lamb, goat and pork. Beef is predominantly produced in central regions of

Otjozondjupa, Omaheke, and Kunene, while mutton and lamb is produced in the arid regions of Hardap, Karas and Erongo (BON, 2004).

2.2.1.1. Beef

The major beef producing areas in Namibia lie in the north and east central regions. Beef is produced both in the commercial and communal areas. Within the communal areas however, production remains constrained by the lack of land tenure which has resulted to over-grazing. This situation has been aggravated by the tendency of large farmers fencing off significant portions of land thus leaving small farmers with little grazing land (BON, 2004). The commercial sector on the other hand is highly capital intensive and has a high usage of fattening products.

Some of the most common problems hampering cattle farming are: Bush encroachment, poor selection of breeds, the low bull to cow ratio, foot and mouth disease climate and uncertainties emanating from the land reform process. Other constraints include the inactive involvement of the Ministry of Agriculture, Water and Forestry in extension work, the exchange rate volatility, and availability of slaughter able cattle, meat quality and marketing channels.

The appreciation of the domestic currency has adverse effects in terms of reducing the revenue of farmers. Moreover, there is a requirement that for cattle from the northern communal areas (NCA) to enter the South African market, they must be kept in quarantine farms for 21 days. A problem associated with this arrangement is that these cattle often lose weight in these camps as a result of insufficient feeding lots, thus leading to low prices obtained on these animals and subsequently discouraging farmers from marketing more of their cattle.

2.2.1.2. Small stock (sheep and goats)

Small stock production is the key agricultural activity in the arid southern parts of Namibia. According to the Agricultural census of 2004, sheep accounted for about 57 percent of the total production of small stock in Namibia, while goats accounted for the remaining 43 percent (BON, 2004). When disaggregated according to breed types, the Dorper sheep is the principal breed which accounted for about 36 percent of the total production of the small stock, followed by the Boar goat with 21 percent. The Karakul sheep, accounted for only 4.4 percent, while the remaining 38.6 percent was accounted for by other sheep and goats. The Dorper is well known for the production of meat while the Karakul sheep is bred primarily for pelts. The Marketing of small stock registered a decrease of 11.2 percent from 1,183,398 in 1995, to 1,050, 297 in 2005.

Similar to beef, sheep farming, more particularly the Karakul is constrained by low supply. This situation is aggravated by the lack of resources to purchase breeding stock as well as the land reform uncertainties. In this regard, the Karakul Board, in association with Agra, the society of the Karakul breeders and the Ministry of Agriculture, Water and Forestry has considered a number of key projects to increase the production of Karakul. These include among others the ram project, the Kunene South project and training. The ram project is aimed at reviving the breeding of Karakul sheep in the communal areas.

On the part of goats, available statistics show that a significant number of goats are produced in rural Namibia, which accounted for about 73 percent of the total production of goats in 2004. One of the problems cited which affects the marketing of goats, is the non-existence of a market for goat meat cuts. Accordingly, about 90 percent of goats are often sold on hoof to South Africa. A potential market for goat meat has recently opened in the USA. Namibia should therefore strategize to enter this market (Mushendami, Biwa, & Gaomab II, 2008).

2.2.2. Crop farming

Pearl Millet, commonly known as "Mahangu", is the major crop cultivated in Namibia, followed by white maize and wheat. To substantiate this point, about 96, 370 tons of Mahangu were produced in 2004 compared with only 55,597 tons of maize in the same year. Other crops cultivated in Namibia include grapes, dates and horticultural crops (MAWF, 2005).

2.2.2.1. White maize

White maize is the major commercial crop produced in Namibia and its harvesting fluctuates with the rainfall conditions. Maize is planted either under dry land, irrigation based methods or both (Namibian Agronomic Board Annual reports, 2004). Dry-land white maize is mainly produced in the maize triangle situated between Grootfontein, Otavi and Tsumeb, Omaheke, and the Caprivi Region. Irrigation based maize production on the other hand is cultivated at the Hardap irrigation scheme, the Naute Project, Etunda, the Katima Farm, Musese, Shitemo, Shadikongolo and Mashare. An increasing amount of white maize under irrigation is also produced at Stampriet, Tsumeb, Grootfontein, Kombat and Otavi areas. Namibia depends on the import of maize particularly from South Africa for consumption purposes.

2.2.2.2. Wheat

Wheat is planted under irrigation in winter (June/July) for harvesting during November/early December of each year. Similar to white maize, wheat is produced at the Naute project, the Hardap irrigation project, the Shadikongolo and in small quantities in the Otavi and Kombat areas. Wheat marketed in Namibia increased significantly by 89 percent from 6,000 tonnes in 1994/95 to 11,340 tonnes in 2004/05 (Namibian Agronomic Board Annual reports, 2004). Namibia is far from self-sufficient in terms of wheat production and depends heavily on imports to meet its consumption demand.

2.2.2.3. Mahangu

Mahangu is cultivated primarily in the North Central Regions (NCRs), Kavango and Caprivi and it is the leading crop grown in Namibia. The total production of Mahangu increased drastically by 64 percent from 34,629 tonnes in 1996 to 96,370 tonnes in 2004 (Namibian Agronomic Board Annual reports, 2004).Contrary to wheat and maize, Mahangu is mostly utilized for domestic consumption only. Traditionally, Mahangu has been viewed as a crop utilised mainly as household food, in addition to supporting needy neighbours or friends.

According to the Namibian Agronomic Board Annual reports (2004), In the Northern regions, the lack of infrastructure and the existence of long distances between towns and millers were identified as problems affecting the trade of Mahangu. These problems were further exacerbated by the lack of technical and maintenance skills of millers as well as the lack of storage facilities. Available information indicates that the Government has envisaged setting up a Mahangu storage facility in the northern communal areas beginning with a pilot project in the Caprivi. Unlike wheat and maize, Mahangu grains have not been imported from other countries. A possible source of imports in times of drought and scarcity of Mahangu is Angola. The constraint is however, the 25 percent import duty requirement. This import duty makes the imports rather expensive and thus stifles trade.

2.3. Taxonomy and ecology of *A. karroo*

A. karroo, also known as the sweet thorn, is the most extensively distributed and abundantly available Acacia species in Southern Africa with a mean density of between 400 and 800 plants/ha (O'Connor, 1995). The sweet thorn belongs to the subgenus Acacia with mainly polyploid species with thorns and capitate inflorescences (Pooley, 1998). The plant occupies a diverse range of habitats and is regarded as a variable polymorphic species. Some of the more distinct ecotypes were mentioned by Ross (1979) and are now recognised as separate species (Coates Palgrave, 2002). *A. karroo* is propagated from seeds and is generally a fast growing, small to medium sized thorn tree (van Wyk et al., 2000). It is deciduous, but may be almost evergreen under favourable conditions (Pooley, 1998). The tree usually has some leaves on the branches at all times of the year, even during periods of drought (Barnes et al., 1996). It is adapted from sea level to 1800m on soils ranging from sand to heavy clays, in areas with an annual rainfall lower than 200mm to as high as 1500mm (Pooley, 1998). The tree also grows on acidic infertile soils with large temperature variations (Barnes et al., 1996). The plant has a long taproot which enables it to use water and nutrients from deep within the soil profile (van Wyk et al., 2000). *A. karroo* is capable of withstanding intense and frequent defoliations (Teague and Walker, 1988). These positive attributes offer added advantages for its use as a sustainable protein supplement for goats in dry areas.

Despite the positive adaptation characteristics, if an area is disturbed or over or under-utilised, *A. karroo* becomes invasive (O'Connor, 1995; Smet and Ward, 2005). It has been labelled as one of the dominant woody species that exacerbates the problem of bush encroachment in Southern Africa (Nyamukanza and Scogings, 2008). Research has evaluated use of various options for controlling its encroachment. These include use of chemical treatments (Smit et al., 1999). Although efficient, these technologies are not economically viable. Use of browsers such as goats, especially in tandem with fire or lopping is effective in controlling *A. karroo* invasiveness (Smit et al., 1999; Nyamukanza and Scogings, 2008). Such an approach is, however, not applicable in rural areas where there are no fences, grass fuel loads are low, and rangelands are communally owned.

Effective control of *A. karroo* in communal areas should involve simple and low cost techniques such as lopping using homemade tools. Leaves from the lopped trees can be harvested and utilised as livestock feed while branches and tree trunks can be used for fencing, firewood, or brush packing in eroded areas. Pods can be ground to enhance protein availability for livestock and reduce the number of intact seeds passing through the animal leading to reduced seedling emergence (Mlambo et al., 2004). Lopping and collection of *A. karroo* leaves and seeds for livestock feeding might simultaneously reduce bush encroachment and improve rangeland and animal productivity in Southern Africa.

2.4. Feasibility of utilising *A. karroo* leaves for smallholder livestock production

A. karroo leaf meal contains between 100 and 160 g crude protein (CP) per kg of dietary dry matter (DM) (Aganga et al., 2000; Halimani et al., 2005). One 2.0m tall tree can produce up to 1 kg of leaf meal per annum. The recommended optimum plant density for *A. karroo* ranges between 500 and 1000 plants/ha (O'Connor, 1995; Barnes et al., 1996), which translates to a leaf meal biomass yield of 1000 kg/ha/annum. Since *A. karroo* is adapted and widely distributed in dry areas, easily propagated from seed (Scogings and Mopipi, 2008), has high growth rates and coppicing ability (Barnes et al., 1996), it is possible to get sufficient and continuous supply of leaf meal for sustainable beef production in semiarid areas.

2.5. Nutritive value of *A. karroo* leaves

2.5.1. Chemical composition and digestibility

In Southern Africa, Acacia species such as *A. karroo* have been reported to be a valuable source of forage for herbivores, particularly during dry periods (Aganga et al., 2000; Dube, 2000; Tefera et al., 2008). *A. karroo* leaves contain high levels of CP (154.0 g/kg DM)) and essential amino acids (Ngwa et al., 2002; Halimani, 2002). The CP levels for *A. karroo* leaves compare favourably with values for other indigenous Acacia species (Aganga et al., 2000; Abdulrazak et al., 2000; Ngwa et al., 2002; Mokoboki et al., 2005). More importantly, the CP values for *A. karroo* are within the optimal range of 110–160 g CP/kg DM required for finishing steers (National Research Council, 2000; Gleghorn et al., 2004). This makes *A. karroo* a potentially important CP supplement for cattle grazing low quality forages.

A. karroo leaves have moderate levels of detergent fibres (table 2.1). Fibre contents for *A. karroo* are consistent with what has been reported in other work with Acacia (Topps, 1997; Maasdorp et al., 1999; Abdulrazak et al., 2000). Given that *A. karroo* has a high CP content and moderate levels of detergent fibres, the relatively low CP digestibility values (i.e., 300–400 g/kg DM) might be ascribed to the presence of phenolic compounds (Rubanza et al., 2005b; Tefera et al., 2008).

Table 2.1: Nutritive value (g/kg dry matter) of Acacia karroo leaves

	Mean	SD
Dry matter (DM)	922.0	22.51
Crude protein	154.0	46.00
NDF	450.0	150.01
ADF	300.0	100.10
Fat	20	2.11
In vitro DM degradability	462.5	2.51
Organic Matter (OM) degradability	439.0	11.03
Apparent digestibility coefficient of DM	520.0	130.21
Apparent digestibility coefficient of CP	350.0	50.31
Apparent digestibility coefficient of NDF	435.0	105.12
Apparent digestibility coefficient of ADF	350.0	50.22
Total phenolics	25.7	5.63

Sources: Aganga et al. (1998, 2000), Dube et al. (2001), Kahiya et al. (2003), Ngwa et al. (2002), Halimani (2002), Halimani et al. (2005), Mokoboki et al. (2005), Nyamukanza and Scogings (2008), Scogings and Mopipi (2008), Mapiye (2009) and Mapiye et al. (2009b).

Table 2.2: Mineral (g/kg DM) and fatty acid (g fatty acid/kg DM) profiles of *A. karroo* leaves.

	Mean	**SD**
K	1.4	0.45
Ca	27.4	10.35
P	1.5	0.35
Mg	3.6	0.35
Fe (mg/kg)	237.5	98.51
Lauric acid	11.5	1.07
Myristic acid	38.5	0.38
Palmitic acid	287.4	0.191
Stearic acid	91.6	1.07
Oleic acid	58.0	0.95
Linoleic acid	169.4	1.59
α-Linolenic acid	343.6	0.61
SFA	429.1	2.32
MUFA	58.6	1.11
PUFA	512.9	2.16

Sources: Aganga et al. (2000), Ngwa et al. (2002), Mapiye (2009) and Mapiye et al. (2009b,c, in press).

A. karroo has a favourable mineral profile (Table 2.2). Its values for Ca, P and Mg are relatively higher than those of related Acacias such as A. tortilis and Acacia nilotica (Aganga et al., 1998; Abdulrazak et al., 2000; Ngwa et al., 2002; Tefera et al.,2008). Calcium,Mg, Fe and Zn values in Table 2.2 are above the recommended levels for beef cattle (National Research Council, 2000). Concentrations of Ca and Mg in *A. karroo* foliage peak in the dry periods (Barnes et al., 1996). The plant also has higher proportions of desirable fatty acids such as α-linolenic acid (ALA; Table 2) compared to other Acacias (Vijayakumari et al., 1994). For ruminants, fatty acids in meat are linearly related to the presence of some of their precursors in the diet (Frenchet al., 2000). Use of *A. karroo* as a supplement might, therefore, increase the proportions of desirable fatty acids in beef.

Variation in the nutrient content of *A. karroo* leaves in Tables 2.1 and 2.2 can be attributed to differences in populations, soil, climate, season, stage of growth, browsing pressure, assay methods and presence of secondary compounds (Aganga et al., 2000; Rubanza et al., 2005b). Overall, the nutritive value of *A. karroo* leaves is high in young plants in the growing season and increases with soil fertility (Aganga et al., 2000; Scogings and Mopipi, 2008). *A. karroo* is a promising CP supplement provided that the adverse effects of anti-quality factors, particularly thorns and tannins are reduced.

2.6 Anti-quality factors and strategies for overcoming their detrimental effects

2.6.1. Thorns

Thorns restrict leaf accessibility and retard rate of nutrient ingestion by restricting bite size of browsers (Cooper and Owen-Smith, 1986; Teague, 1989; Belovsky et al., 1991). According to Wilson and Kerley (2003), removal of thorns from *A. karroo* branches increases bite sizes and feed intake rates. Removal of thorns is however, not a feasible alternative, especially when feeding medium to large herds. It is worthwhile to develop a more practical and low cost strategy of collecting leaves for feeding such herds.

Recent work by Mapiye et al. (2009b, 2010b) has shown that relatively large quantities of *A. karroo* leaf meal can be conveniently harvested by selectively cutting small trees (i.e., 1.5–2.0m tall) or branches with an axe, handsaw, chainsaw, or diesel powered saw. The lopped branches are then stacked up to 1.5m high on polythene sheets of manageable size placed in the rangeland. Cutting should be between 15 and 30cm above the ground at a slanting angle to prevent rotting of the stump and promote coppicing (Dzowela et al., 1995). The leaves are left to dry in the sun for 2–4 days to reach a DM content of between 0.8 and 0.85 (Srivastava & Sharma, 1998). After drying leaves are collected from the polythene sheets by shaking them off the branches. To minimise moisture spoilage of leaves, harvesting should be in the post rainy season.

Dried leaves are then sieved through a 2–4mm sieve to separate them from thorns, twigs and exploded pods, which can inhibit intake (Kaitho et al., 1997; Maasdorp et al., 1999). During harvesting, protective clothing such as thorn-proof work suits and gloves, goggles, helmets, and safety shoes should be worn for protection against thorns (Mapiye, 2009).

Collected leaf meal can be bagged and stored in well ventilated shade or storeroom until fed. The effect of duration of leaf meal storage prior to feeding on nutritive value is not known and deserves investigation. Tannin concentrations, for example, have been reported to decrease with storage duration, leading to improved DM degradability of the browse tree leaves (Makkar and Singh, 1993). Even though leaf meal harvesting is a labour intensive process, it is inexpensive and has potential to create employment opportunities for rural dwellers. However, the search for less laborious leaf meal harvesting technologies is essential. Besides thorns, phenolics also deter herbivory of *A. karroo* leaves.

2.6.2. Phenolic compounds

Sweet thorn contains high levels of extracted condensed tannins (i.e., 55–110 g extracted condenses tannin/kg DM; Dube et al., 2001; Mokoboki et al., 2005) compared to the range of 20–80 g/kg DM considered beneficial to ruminants (Mueller-Harvey, 2006). Abdulrazak et al. (2000) and Rubanza et al. (2005a) also reported high and variant contents of phenolics in other indigenous Acacias. The large variation of *A. karroo's* phenolic compounds could be a result of differences in ecotypes, seasons, ecological zone, soil type, age of the plant and nature of the assays used (Mueller-Harvey, 2006; McSweeney et al., 2008). The concentration of phenolic compounds is highest in leaves of old plants during the dry season, especially in soils of low fertility (Scogings & Mopipi, 2008).

Condensed tannins in *A. karroo* have been implicated in increasing faecal N and negative N retention in goats (Dube & Ndlovu, 1995). There are few reports on the effects of condensed tannins in *A. karroo* on digestibility and animal performance.

Overall, effects of condensed tannins on digestibility and utilisation of feeds depend on tannin concentration, structure and chemical nature, the nature of tannin activity, structure–activity relationships, and biological activity (Schofield et al., 2001;

Mueller-Harvey, 2006; McSweeney et al., 2008). Hence, parameters such as molecular weight and solubility of tannins in water versus organic solvents have become more important than simply tannin concentration (Mueller-Harvey et al., 2007). For *A. karroo*, little is however known about such parameters and, thus, they merit research. To improve utilisation of *A. karroo* leaves as a CP supplement, development of novel, simple and cost-effective detanninification approaches is also crucial.

Several methods have been used to alleviate deleterious effects of tannins in browse trees. Among these are use of alkalis (e.g. urea, ammonia, calcium hydroxide, sodium hydroxide, potassium hydroxide; Makkar and Singh, 1993; Vitti et al., 2005), chelating metal ions (Price et al., 1979), and oxidising agents (e.g. potassium dichromate, potassium permanganate; Makkar and Singh, 1993; Makkar, 2003). Despite being effective for overcoming acute toxic effects of tannins (Mueller-Harvey, 2006), alkalis, metal ions and oxidising agents require expertise, result in large losses of soluble nutrients and are corrosive (Vitti et al., 2005). Moreover, if mismanaged, they can be poisonous to people and animals and are not environmentally friendly (Ben Salem et al., 2005; Vitti et al., 2005). Wood ash and charcoal are inexpensive and locally available sources of alkali (Makkar, 2003; Ben Salem et al., 2005), but may not be available in large quantities for sustainable utilisation in low input production systems. Evaluating the capacity of *A. karroo* wood ash to de-activate tannins and improve the protein value of its leaves might enhance its adoption as an animal feed. Tannin binding compounds such as polyethylene glycol and polyvinyl-pyrrolidone (Priolo et al., 2005; Mlambo et al., 2007).

Although effective, the limited availability and high cost of microbial enzymes and tannin binding compounds makes their application impractical and unprofitable under low input cattle production systems (Makkar, 2003; Ben Salem et al., 2005). Oven, freeze, and sun air drying techniques have also been used to lessen the adverse effects of phenolics in browse legumes (Dzowela et al., 1995; Stewart et al., 2000; Vitti et al., 2005). Oven and freeze drying methods require expertise, sophisticated equipment and electricity (Ahn et al., 1997; Stewart et al., 2000), which may not be available in rural communities in Southern Africa. Though less effective compared to other methods, sun air drying is a simple, inexpensive and sustainable technique that makes use of readily and abundantly available resources (Dzowela et al., 1995). Sun air drying could, therefore, be a more acceptable and feasible alternative for resource poor beef producers.

2.7. *Acacia karroo* as a supplement for goats

2.7.1. Browse trees to grass species preference by goats

Goats are browsers, choosy and sensitive to the kind of feed they take. They select for leaves and tender stems and can refuse up to 50% of feed offered (Rangoma, 2011). Their small mouth, narrow muzzle and split upper lips enable them to pick small leaves, flowers, fruits and other plant parts, thus choosing only the most nutritious available feed (Aganga, Tsopito, & Adogla-Bessa, 1998). As natural browsers, given the opportunity, goats will select over 60 percent of their daily diet from brush and woody perennials over herbaceous species (Provenza, 1995). The ability to utilize browse species, which often have thorns and an upright growth habit with small leaves tucked among woody stems, is a unique characteristic of the goat, compared to heavier, less agile ruminants.

Although goats have definite plant preferences, they show high variability in feeding habits in different ecological zones as well as seasonal variation within the same region (McCammon-Feldman et al., 1981). On average, goats select about 60% shrubs, 30% grass, and 10% forbs on a year-long basis. Similar results were found at Fort Hare with Boer goats on False Thornveld of the Eastern Cape which spent on average 61 % and 39 % of their active feeding time browsing and grazing (grass and forbs), respectively (Raats et al., 1996).

In a recent study (Grova and Bjelland, 1997) conducted on rested False Thornveld during Winter, goats were found to spent 2½ times as much browsing than grazing when forage was abundant but this ratio was reversed when forage became limited.

Table 2.3: Effect of season on goat browse to grass consumption

Month	**Shrubs (%)**	**Forbs (%)**	**Grasses (%)**
Summer	84	11	5
Winter	79	13	8
Annual means	82	11	7

Adapted from Ramirez (1999)

According to Ramirez (1999), grasses represented the group of plants that were less consumed by goats (Table 2.1) throughout the year. In winter, goats select the highest amount of grasses, probably because of the growth of grasses during this period. Papachristou and Nastis (1993) experimentally demonstrated that goats exhibit very rapid seasonal shifts between shrubs, grasses and forbs, depending on their availability and their seasonal nutritive value. Similar results on the preference of grass to browse species were also reported in earlier studies (Pfister & Malechek, 1986).

The ability of ruminants to select feed depends greatly on past experience, as familiar feed is always preferred to new feed. Goat preference for shrubby species is also affected by the abundance of shrubby species in particular zones and accessibility (le Houerou, 1980). Goats rely on browse species, which do not decline in quality to the same degree as herbaceous species (Sanon et al., 2007), to supplement the protein, minerals and vitamins in their diet (le Houerou, 1980). The nutritive value of browse species is known to be high, with lower variation over time, when compared to grasses (Fadel Elseed et al., 2002).

2.7.2. Intake of browse plants (*Acacia karroo*) by goats

Goats prefer the leaves and twigs of trees containing condensed tannins (CT) and digest them better than other forage eating ruminants (Villena & Pfister, 1990; Lee, Lee, Lee, 1990; Silanikove, 2000). Goats are primarily browsers, and in most areas browse constitutes 60-80% of goat diets (Kababya, 1995). They are able to consume larger amounts of tannin-rich browse than sheep under similar conditions (Gilboa, Nir, Nitsan, Silanikove, & Perevolotsky, 1995; Silanikove, Gilboa, Perevolotsky, & Nitsan, 1996). They inevitably select the leaves in preference to the stems, as leaves have much higher concentration of CT.

The voluntary intake and leaf selection of tannin plants such as A. karroo is, however, highly disturbed by the presence of thorns (Mapiye, Chimonyo, Marufu, & Dzama, 2011), which restrict the accessibility of the leaves and phenolic compounds (Teague, 1989). Reduced intake, degradability and nutrient availability (Mokoboki et al., 2005), as well as the intestinal absorption of proteins and carbohydrates (Giner-Chavez, 1996) are associated with the phenol compounds present in tanniferous plants.

Robbins et al. (1987); Silanikove, Nitsan, and Perevolotsky (1994); Silanikove et al. (1996) established a relationship between the intake of a high level of tannin forage plants, palatability, digestibility and nitrogen (N) retention in small ruminants. Unfortunately; the relationship that was found produced negative effects of tannins in ruminants as it resulted in reduced feed intake, palatability, low rate of evacuation of digesta out of the rumen and toxic effects (Kumar & Singh, 1984; Provenza, 1995). Tannins increase the-N-content of faeces and decrease urinary N output (Waghorn & McNabb, 2003). The low intake of *ad libitum* browse containing tannins by goats can further be improved by the provision of polyethylene glycol (PEG) (Waghorn, 2008). Villalba, Provenza, and Banner (2002) reported that access to PEG resulted in an increased intake of a pelleted tanniferous diet by sheep and goats. Recently, the use of PEG to diminish the negative effects of condensed tannins offers good potential to improve goat production (Waghorn, 2008).

Condensed tannins are secondary plant compounds generally regarded as toxic to animals when consumed in large amounts (Rojas et al., 2006). Normally, animals consuming tannin-rich feeds appear to develop defensive mechanisms against tannins

(Makkar, 2003) given that, under very high levels of tannin intake by animals, the tannin compounds might negatively affect protein utilization (Pell, Mackie, Mueller-Harvey, & Ndlovu, 2001). However, they can produce toxicity and can even cause death (Garg et al., 1992). Animals in tropical and dry environments are more prone to this, since trees and shrubs are an important source of fodder for livestock (Topps, 1992) though they tend to contain higher amounts of tannin than temperate plants (Rojas et al., 2006). Niezen, Waghorn, Raufaut, Robertson, and McFarlane (1994) reported that levels of condensed tannins vary between different plant species.

2.7.3. Nutritive value of browse plants and the beneficial effect on goats

According to Mandal (1997), nutritive value is a function of feed intake (FI) and the efficiency of extraction of nutrients from the feed during digestion. Fodder trees and shrubs represent an enormous potential source of protein for ruminants in the tropics (Ngongoni, Mapiye, Mwale, & Mupeta, 2007). Some of these species are highly digestible, providing nutrients to rumen microorganisms (Umunna, Nsahlai, & Osuji, 1995) and can increase voluntary intake. The main features of browse plants are their high crude protein (CP) (100–250 g/kg DM) and mineral contents (Mokoboki et al., 2005; Devendra & Sevilla, 2002), however they have antihelmintic properties (Xhomfulana, Mapiye, Chimonyo, & Marufu, 2009) and a high content of secondary plant metabolites (Monforte-Briceño, Sandoval-Castro, Ramírez-Avilés, & Capetillo, 2005).

The Acacia species are reported to be a valuable source of forage for ruminants where feed quality is a production constraint (Goodchild & McMeniman, 1994). This could be attributed to the fact that the Acacia species can easily meet nutrient requirements, mainly proteins (Aganga, Tsopito, & Adogla-Bessa, 1998; Kahiya, Mukaratirwa, & Thamsborg, 2003; Mokoboki et al., 2005) and minerals (Aganga et al., 1998; Mokoboki et al., 2005) relative to other palatable indigenous plants without condensed tannins.

According to Rubanza, Shem, Otsyina, and Fujihara (2005), the concentration of crude protein in leaves of the majority of fodder trees and shrubs is above 10% even in the dry season when it tends to decrease. Generally, calcium and potassium contents are higher than other minerals. The role of trees and shrubs in the supply of vitamins is indirectly demonstrated by the fact that browsers such as goats contract photophobia, which many large ruminants such as cattle are prone to during the dry season. In ruminants dietary condensed tannins (2–3%) have been shown to impart beneficial effects (Hoste, Jackson, Athanasiadou, Thamsborg, & Hoskin, 2006) that are associated with their anthelminthic properties and anti-oxidant effects (Saura-Calixto, Serrano, & Goñi, 2007). The dietary tannins reduce the wasteful protein degradation in the rumen by the formation of a protein-tannin complex (Barry, 1987; Min & Hart, 2003).

Tannin plants such as *A. karroo* improve the nutritional status, growth performance and carcass traits (Mapiye et al., 2009), and reduces nematode burdens (Niezen et al., 1998; Xhomfulana et al., 2009) in ruminants. Tannin plants affect the biology of the H. contortus especial in larval stage three. In that way, it controls the parasitic populations (Niezen et al., 1998).

2.7.4. Nutritive value of browse plants and beneficial effect on meat quality of goats

According to Mandal (1997), nutritive value is a function of feed intake (FI) and the efficiency of extraction of nutrients from the feed during digestion. Fodder trees and shrubs represent an enormous potential source of protein for ruminants in the tropics (Ngongoni, Mapiye, Mwale, & Mupeta, 2007). Some of these species are highly digestible, providing nutrients to rumen microorganisms (Umunna, Nsahlai, & Osuji, 1995) and can increase voluntary intake. The main features of browse plants are their high crude protein (CP) (100–250 g/kg DM) and mineral contents (Mokoboki *et al.*, 2005; Devendra & Sevilla, 2002), however they have antihelmintic properties (Xhomfulana, Mapiye, Chimonyo, & Marufu, 2009) and a high content of secondary plant metabolites (Monforte-Briceño, Sandoval-Castro, Ramírez-Avilés, & Capetillo, 2005).

The *Acacia* species are reported to be a valuable source of forage for ruminants where feed quality is a production constraint (Goodchild & McMeniman, 1994). This could be attributed to the fact that the *Acacia* species can easily meet nutrient requirements, mainly proteins (Aganga, Tsopito, & Adogla-Bessa, 1998; Kahiya, Mukaratirwa, & Thamsborg, 2003; Mokoboki *et al.*, 2005) and minerals (Aganga *et al.*, 1998; Mokoboki *et al.*, 2005) relative to other palatable indigenous plants without condensed tannins.

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The complex appears to dissociate post-ruminally at a low pH where, apparently, the protein becomes available for digestion (Cossalter, 1986). However, free condensed tannins would probably be available to form a complex with digestive enzymes such as pepsin and also with the protein of gut wall. In addition, tannin plants such as *A. karroo* improve the nutritional status, growth performance and carcass traits (Mapiye *et al.*, 2009), and reduces nematode burdens (Niezen *et al.*, 1998; Xhomfulana *et al.*, 2009) in ruminants. Tannin plants affect the biology of the *H. contortus* especial in larval stage three. In that way, it controls the parasitic populations (Niezen *et al.*, 1998).

CHAPTER 3

METHODOLOGY

3.1. Site description and research materials

The study was carried out at the University of Namibia's Neudamm Campus**,** 30 km east of Windhoek. Neudamm Campus, lies between 22^0 and 23.30^0S and 15.30^0 and 18.30^0E in the Highland savanna of Namibia. The activities on the farm are a combination of small stock (goats and sheep) and large stock (Beef and dairy) farming, as well as poultry, pig and game production. The area receives an annual rainfall of about 3-50 to 400 mm (Mendelsohn et al., 2002). *A. karroo* leaves were collected from within Neudamm farm. A bush cutter was used to harvest *A. karroo* leaves, and the leaves were left to sun dry in the field placed on top of plastic sheets on the ground. Lucerne was purchased from Agra. The ram and ewe pellets were purchased from feed master. The saw dust was obtained from a local company and used as bedding throughout the experiment. Other equipment and consumables such as drinking troughs, feed pens and medication, were provided by the Neudamm farm management. Experimental diets were formulated on a computer and mixed manually. All of the ingredients used to formulate experimental diets were analysed for dry matter, crude protein, energy, crude fiber and ether extract according to the Official Methods of Analysis (AOAC, 2000).

3.2. Animal Management

On arrival the 3 months old Boer goats were given fresh water. The goats were kept in the same shed house and fed with a commercial feed for the first three weeks. The goats were vaccinated against pulpy kidney. Goats were also dosed with orange straw bales (strooibale) against internal parasites. Goats on the same treatment were kept in one paddock. The goats on the supplementary diets were allowed 21 days to adapt to the experimental conditions. These goats were trained for 14 days during the adaptation period to feed from troughs.

3.3. Research design

Quantitative research was used whereby 16 goats were used in the experiment. The controls were goats fed with a commercial feed without *A. karroo* leaves supplement. The experiment were goats fed on *A. karroo* leaves at different levels 0%, 10%, 20% and 25% respectively while keeping all diets iso-nitrogenous and iso-energetic. The goats were assigned to the treatments using a completely randomised design (CRD) with a 2 (sex) x 4 (*A. karroo* inclusion level) factorial arrangements of treatments where initial weight was used as a co-variate. The weights of the goats due to same age and coming from the same flock were very close. The goats were assigned to four treatments, each with two replications and each replication having two goats. Thus, a total of eighty pens were used. The experimental treatments were as follows:

S_1T_0: Male Boer goats fed a diet without tanniniferous *A. karroo* leaf meal supplementation.

S_1T_1: Male Boer goats fed a diet supplemented with 10% tanniferous *A. karroo* leaf meal per kg diet.

S_1T_2: Male Boer goats fed a diet supplemented with 20% tanniferous *A. karroo* leaf meal per kg diet.

S_1T_3: Male Boer goats fed a diet supplemented with 25% tanniferous *A. karroo* leaf meal per kg diet.

S_2T_1: Female Boer goats fed a diet without tanniferous *A. karroo* leaf meal supplementation.

S_2T_2: Female Boer goats fed a diet supplemented with 10% tanniferous *A. karroo* leaf meal per kg diet.

S_2T_3: Female Boer goats fed a diet supplemented with 20% tanniferous *A. karroo* leaf meal per kg diet.

S_2T_4: Female Boer goats fed a diet supplemented with 25% tanniferous *A. karroo* leaf meal per kg diet.

3.4. Population

A total of 240 Boer goats at Neudamm Farm was the population.

3.5. Sample

Sixteen (16) Boers goats (three month old) were randomly selected.

3.7. Procedures

Goats were divided into four groups and each group was assigned to a specific diet with different levels of *A. karroo* leaves (0%, 10%, 20% and 25%) respectively. The 0% tanniferous *A. karroo* was the control in the experiment. Each treatment had four replicates. The feed intake of goats in each group was measured on a daily bases and weight measured weekly.

3.8. Data analysis

The data was subjected to analysis of variance using a model that had treatment as the main effect in SAS (2000). Treatment means were compared using Duncan's multiple range test (Duncan, 1955).

3.9. Research Ethics

This study took cognisance of animal welfare issues by ensuring that the people, animals and rangelands were not adversely affected in the process. The goats that were used in the research were placed in a shed house which was well spaced and enough ventilation. The building was also cleaned once per week. Feeds for goats was provided on a daily bases. Water was made available to goats at all the time. People that worked with goats wore safety clothes at the time while carrying out their duties.

CHAPTER 4

RESULTS

4.1. Chemical Composition of *A. karroo*

The proximate analysis for *A. karroo* leaf meal is presented in Table 4.1.

Table: 4.1. Chemical Composition of *A. karroo*

Feed	CP (g/100g)	CF (g/100g)	Ash (g/100g)	Fats (g/100g)	Nitrogen (g/100g)	Moisture (g/100g)	DE Mj/kg	ME Mj/kg
A.karroo	10.2	16.1	8.0	5.4	1.64	7.2	12	10

A. Karroo= Acacia karroo

4.2. Nutrient composition of treatment diets

Nutrient compositions of experimental finisher diets fed to Boer goats from week 3 to week 8 are shown in Table 4.2:

Table 4.2. Nutrient composition of experimental Boer goat finisher diet (3-8 weeks)

Nutrients	**Experimental Diets**			
	T1	T2	T3	T4
Crude Protein %	18.0	17.8	17.9	17.7
Crude Fibre %	32.7	17.8	18.8	16.1
Energy ME/MJ/Kg	11.7	12	11.9	12

T1= Control diet; T2= 10% of Lucerne and pellets replaced with *A. karroo*; T3= 20% of Lucerne and pellets replaced with *A. karroo*; 25% of Lucerne and pellets replaced with *A. karroo*.

The results of the effects of replacing Lucerne and pellets with *A. karroo* on feed intake (kg/goat/day), weight gain (kg/goat/day) and feed conversion ratio (FCR) (kg/feed/kg live weight gain) of Boer goats are presented in the tables 4.3 and 4.4 below:

Table: 4.3. Effects of replacing Lucerne and pellets with *A. karroo* on feed intake (kg/goat/day), weight gain (kg/goat/day) and feed conversion ratio (FCR) (kg feed/kg live weight gain) of Boer goats

Treatments	**ADG**	**VFI**	**FCR**
T1	0.124	1.0100	8.145
T2	0.113	1.0140	8.973
T3	0.123	0.8867	7.209
T4	0.161	1.1942	7.417
Mean	0.130	1.026	7.892

Where ADG= Average daily gain; VFI= Voluntary feed intake; FCR =Feed conversion ratio

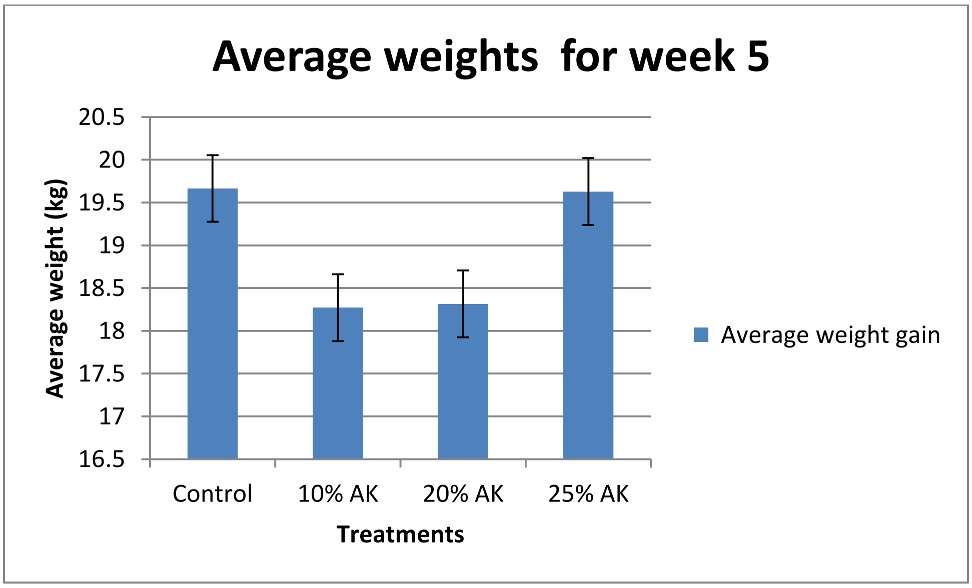
T1= Control diet; T2= 10% of Lucerne and pellets replaced with *A. karroo*; T3= 20% of Lucerne and pellets replaced with *A. karroo*; T4= 25% of Lucerne and pellets replaced with *A. karroo*.

4.3. Average Weight

Table: 4.4 shows the average weights for week 5

Treatments	**N**	**Mean (kg)**	**Std. Error**
Control	4	19.6643	2.03270
10% AK	4	18.2714	1.69078
20% AK	4	18.3143	1.63536
25% AK	4	19.6286	0.38739
Mean	16	18.9696	0.74335

The table above shows the weekly average body weight for the goats assigned in each treatment. Each treatment was assigned four goats, 2 males and 2 females. The weights are slightly varying from treatment to treatment.

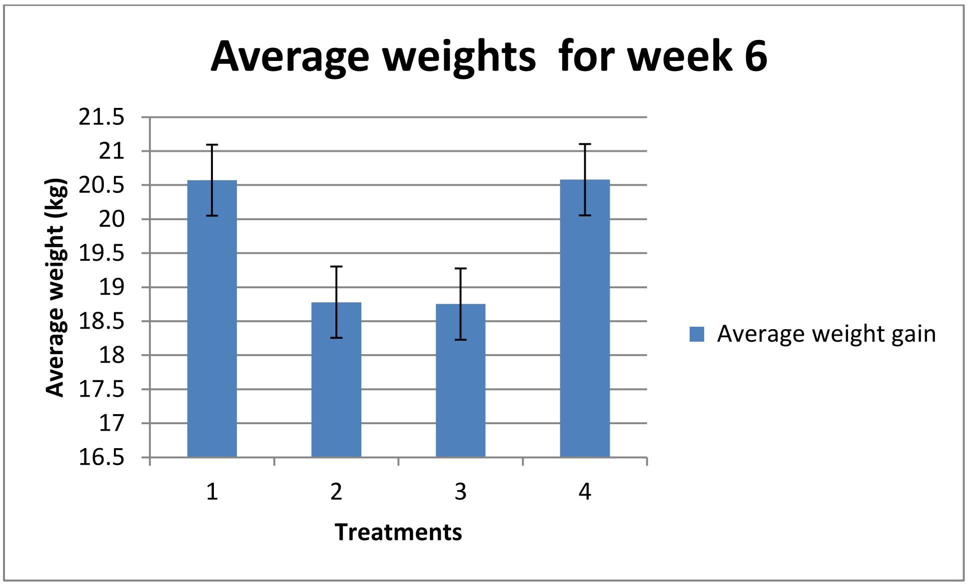


The ANOVA test indicates that there is a significant difference in ADG between the control and treatment 2 and 3 (P<0.05). Treatment 4 (the 25% inclusion level) was not different from the positive control (P>0.05). Since the p-value is less than the significant level (0.05) we conclude that the means of the average body weights in each treatment are significantly different (P<0.05). The control and 25% *A. Karroo* depicted the high average weight (19.63kg). They are both not statistically different from each other. The rest of the treatments showed low average weight and they are both statistically the same.

Table: 4.5. Shows the average weights for week 6

Treatments	**N**	**Mean (kg)**	**Std. Error**
Control	4	20.5714	**1.**82007
10% AK	4	18.7786	1.81451
20% AK	4	18.7514	1.70419
25% AK	4	20.5802	0.41163
Mean	16	19.6704	0.73612

The table above shows the weekly average body weight for the goats assigned in each treatment. Each treatment was assigned four goats, 2 males and 2 females. The weights are slightly varying from treatment to treatment.

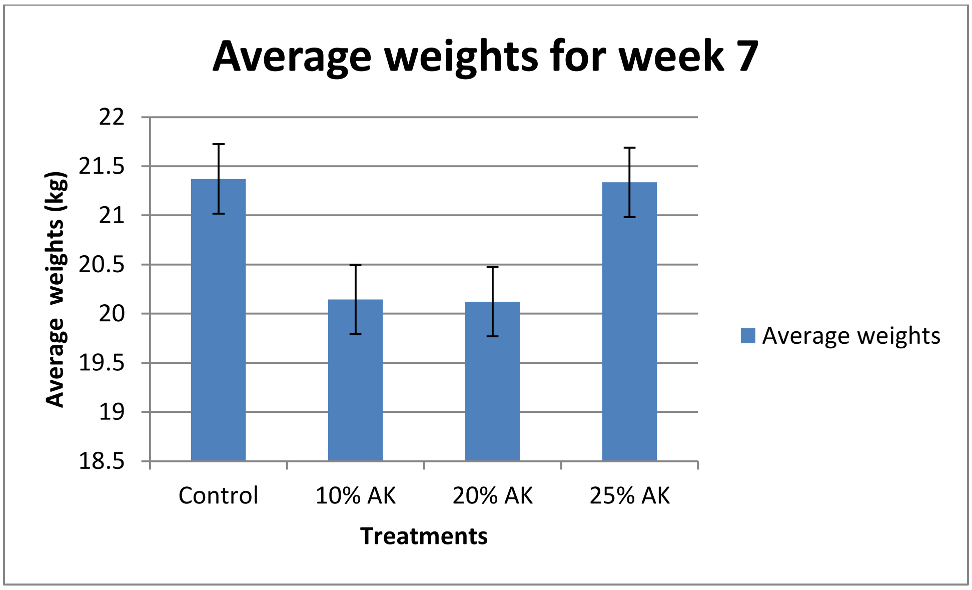


The ANOVA test indicates that there is a significant difference in ADG between the control and treatment 2 and 3 ($P<0.05$). Treatment 4 (the 25% inclusion level) was not different from the positive control ($P>0.05$). The control and 25% *A. Karroo* depicted the high average weight (20.58kg). They are both not statistically different from each other. The rest of the treatments showed low average weight and they are both statistically the same.

Table: 4.6. Shows the average weights for week 7

Treatments	N	Mean (kg)	Std. Error
Control	4	21.3714	1.92599
10% AK	4	20.1457	1.93974
20% AK	4	20.1214	1.33413
25% AK	4	21.3357	0.46546
Mean	16	20.7436	0.73407

The table above shows the weekly average body weight for the goats assigned in each treatment. Each treatment was assigned four goats, 2 males and 2 females. The weights are slightly varying from treatment to treatment.

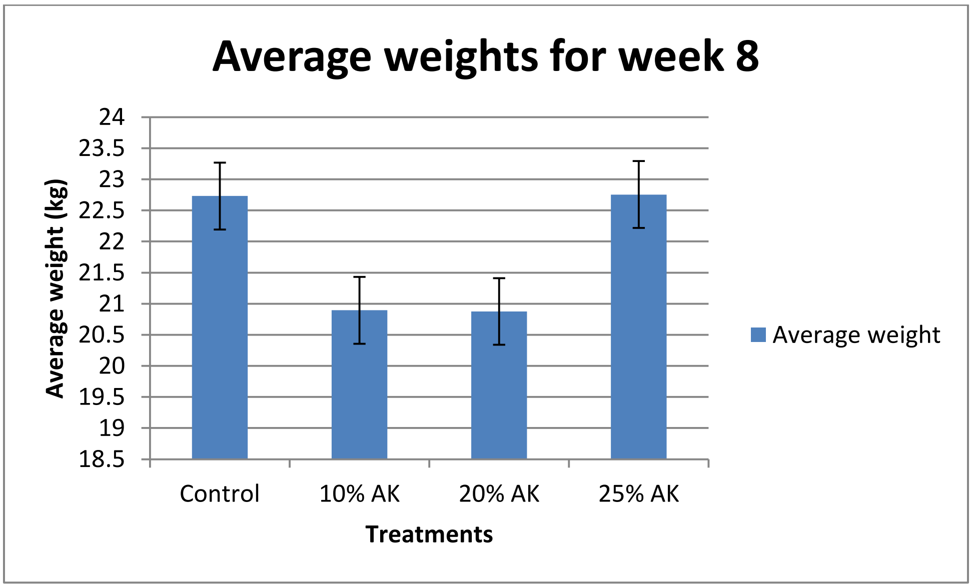


The ANOVA test indicates that there is a significant difference in ADG between the control and treatment 2 and 3 (P<0.05). Treatment 4 (the 25% inclusion level) was not different from the positive control (P>0.05). Since the p-value is less than the significant level (0.05) we conclude that the means of the average body weights in each treatment are significantly different (P<0.05). The control and 25% *A. Karroo* depicted the high average weights (21.34kg). They are both not statistically different from each other (P<0.05). The rest of the treatments showed low average weights and they are both statistically the same (P>0.05).

Table: 4.7. Shows the average weights for week 8

Treatments	N	Mean (kg)	Std. Error
Control	4	22.7313	2.04703
10% AK	4	20.8938	2.09026
20% AK	4	20.875	1.46309
25% AK	4	22.755	0.53327
Mean	16	21.81378	0.78554

The table above shows the weekly average body weight for the goats assigned in each treatment. Each treatment was assigned four goats, 2 males and 2 females. The weights are slightly varying from treatment to treatment.



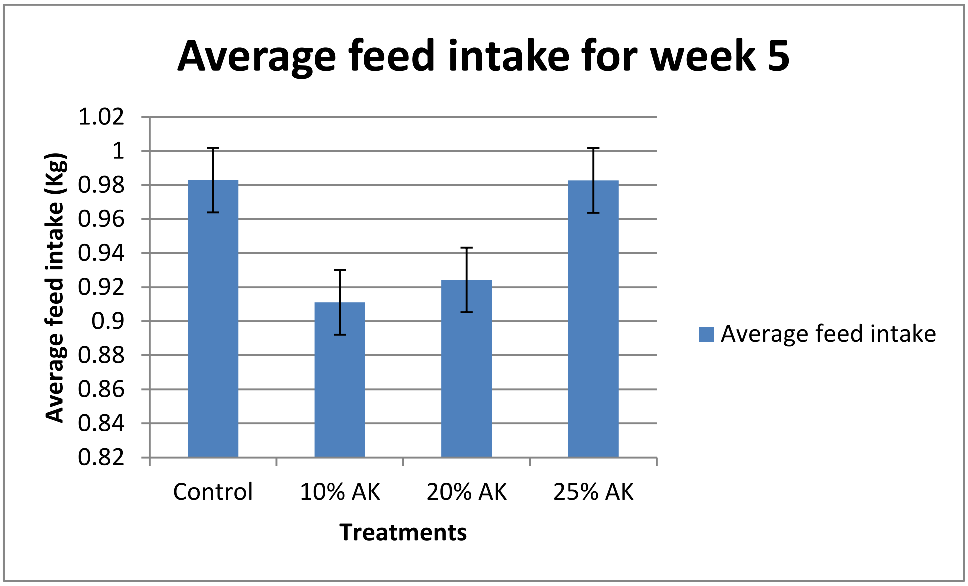
The ANOVA test indicates that there is a significant difference in ADG between the control and treatment 2 and 3 ($P<0.05$). Treatment 4 (the 25% inclusion level) was not different from the positive control ($P>0.05$). Since the p-value is less than the significant level (0.05) we conclude that the means of the average body weight in each treatment are significantly different ($P<0.05$), therefore the hypothesis which says tanniferous *Acacia karoo* leaf meal level of supplementation at finisher stage has no effect on live weight could be rejected. The control and 25% *A. Karroo* depicted the high average weights (21.34kg). They are both not statistically different from each other ($P<0.05$). The rest of the treatments showed low average weights and they are both statistically the same ($P>0.05$).

4.4. Average Feed intake and FCR

Table: 4.8. Shows the average feed intake for week 5

Treatment	**N**	**Mean (kg)**	**Std. Error**
Control	4	0.9829	0.01214
10% AK	4	0.9111	0.00679
20% AK	4	0.9243	0.04071
25% AK	4	0.9827	0.01343
Mean	16	0.95025	0.01554

The table above shows the weekly average feed intake for the goats assigned in each treatment. Each treatment was assigned two goats, 2 male and 2 female. The average feed intakes are slightly varying from treatment to treatment.

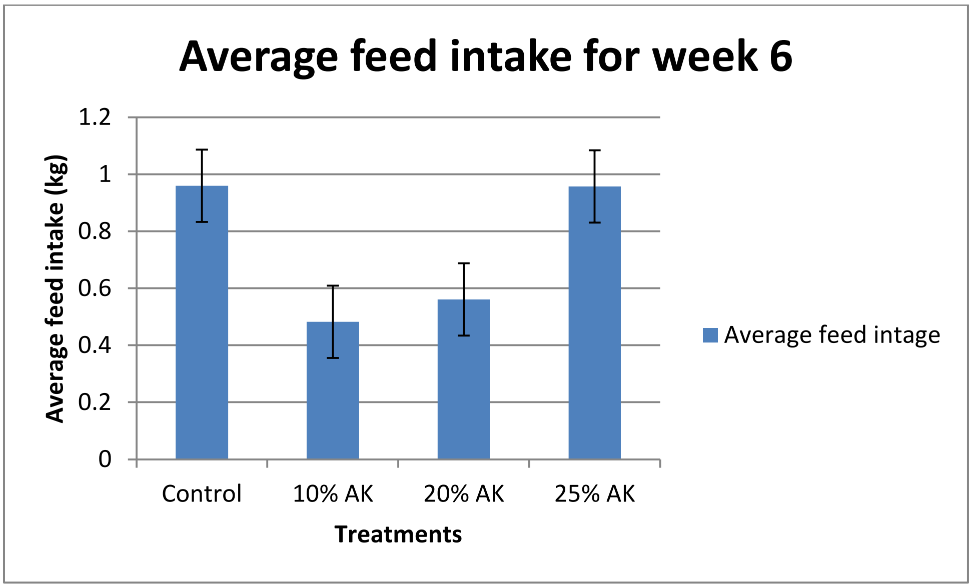


The ANOVA test indicates that there is a significant difference between the control and treatment 4 compared to treatment 2 and 3 (P<0.05). The feed intake increased as the inclusion level of *A. karroo* increased. The best level is 25% *A. Karroo*, (0.98kg feed intake). The control diet is slightly different from the 25% *A. Karroo* but they are not statistically different. Both the 10 and 20% *A. Karroo* showed low feed intake.

Table: 4.9. Shows the average feed intake for week 6

Treatments	N	Mean (kg)	Std. Error
Control	4	0.9593	0.00500
10% AK	4	0.4827	0.00086
20% AK	4	0.5607	0.05357
25% AK	4	0.9568	0.01250
Mean	16	0.7398	0.02175

The table above shows the weekly average feed intake for the goats assigned in each treatment. Each treatment was assigned two goats, 2 male and 2 female. The average feed intakes are slightly varying from treatment to treatment.

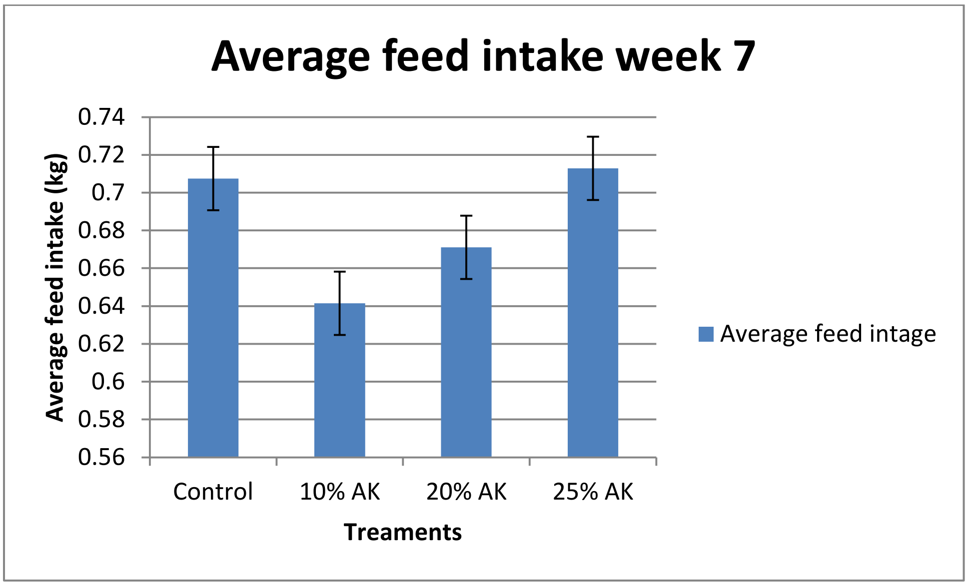


The ANOVA test indicates that there is a significant difference between the control and treatment 4 compared to treatment 2 and 3 ($P<0.05$). The feed intake increased as the inclusion level of *A. karroo* increased. The best level is 25% *A. Karroo*, (0.96kg feed intake). Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly feed intake in each treatment are significantly different (P<0.05). The control diet is slightly different from the 25% *A. Karroo* but they are not statistically different. Both the 10 and 20% *A. Karroo* showed low feed intake.

Table: 4.10. Shows the average feed intake for week 7

Treatment	**N**	**Mean (kg)**	**Std. Error**
Control	4	0.7075	0.03250
10% AK	4	0.6414	0.00936
20% AK	4	0.6711	0.00036
25% AK	4	0.7129	0.00143
Mean	16	0.68323	0.01210

The table above shows the weekly average feed intake for the goats assigned in each treatment. Each treatment was assigned two goats, 2 male and 2 female. The average feed intakes are slightly varying from treatment to treatment.

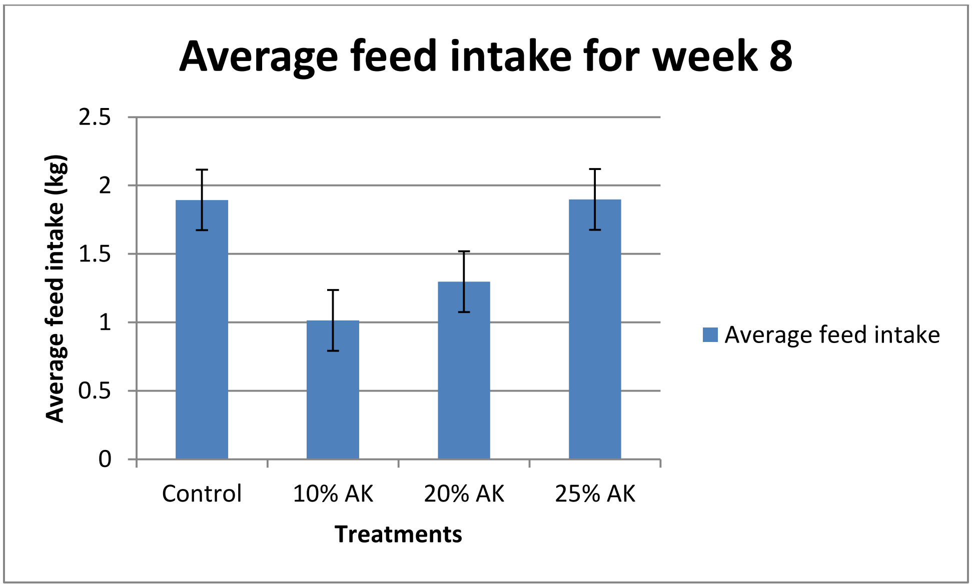


The ANOVA test indicates that there is a significant difference between the control and treatment 4 compared to treatment 2 and 3 (P<0.05). The feed intake increased as the inclusion level of *A. karroo* increased. Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly feed intake in each treatment are significantly different (P<0.05). The control diet is slightly different from the 25% *A. Karroo* but they are not statistically different. In week 7, 25% *A. Karroo* inclusion depicted a higher feed intake (0.71kg). The control feed which is a commercially feed is not statistically different from 25% *A. Karroo*. The 10% A. Karroo level is statistically the same with the 20% *A. Karroo* but statistically different to both control and 25% *A. Karroo*.

Table: 4.11. Shows the average feed intake of Boer goats for week 8

Treatment	N	Mean (kg)	Std. Error
Control	4	1.8945	0.02333
10% AK	4	1.014	0.07067
20% AK	4	1.2967	0.03833
25% AK	4	1.8977	0.13417
Mean	16	1.52573	0.05110

The table above shows the weekly average feed intake for the goats assigned in each treatment. Each treatment was assigned two goats, 2 male and 2 female. The average feed intakes are slightly varying from treatment to treatment.



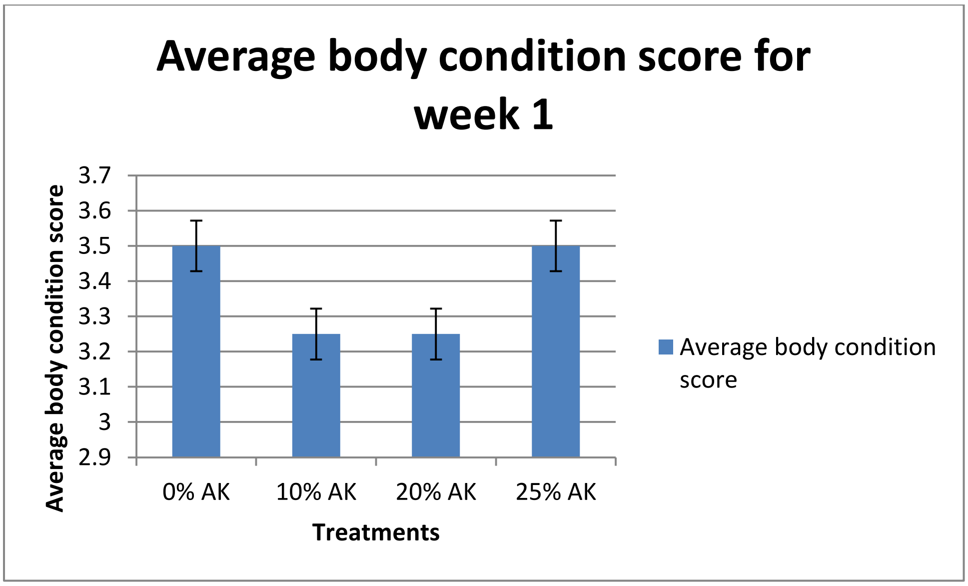
The ANOVA test indicates that there is significant difference between the different treatments ($P<0.05$). Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly feed intake in each treatment are significantly different, therefore the hypothesis which says tanniferous *A. karoo* leaf meal level of supplementation at finisher stage has no effect on feed intake could be rejected. In week 8, 25% *A. Karroo* depicted the higher feed intake (1.90kg) compared to the rest of the treatments. Both the 10 and 20% *A. Karroo* have the same level of feed intake but are both statistically different from the control and 25% *A. Karroo*.

4.5. Average body condition score

Table: 4.12. Shows the body condition score for week 1

Treatments	N	Mean	Std. Error
0% AK	4	3.50	0.289
10% AK	4	3.25	0.479
20% AK	4	3.25	0.408
25% AK	4	3.50	0.289
Mean	16	3.31	0.176

The table above shows the weekly average body condition score for the goats assigned in each treatment. Each treatment was assigned four goats, 2 male and 2 female. The average body condition score are slightly varying from treatment to treatment.

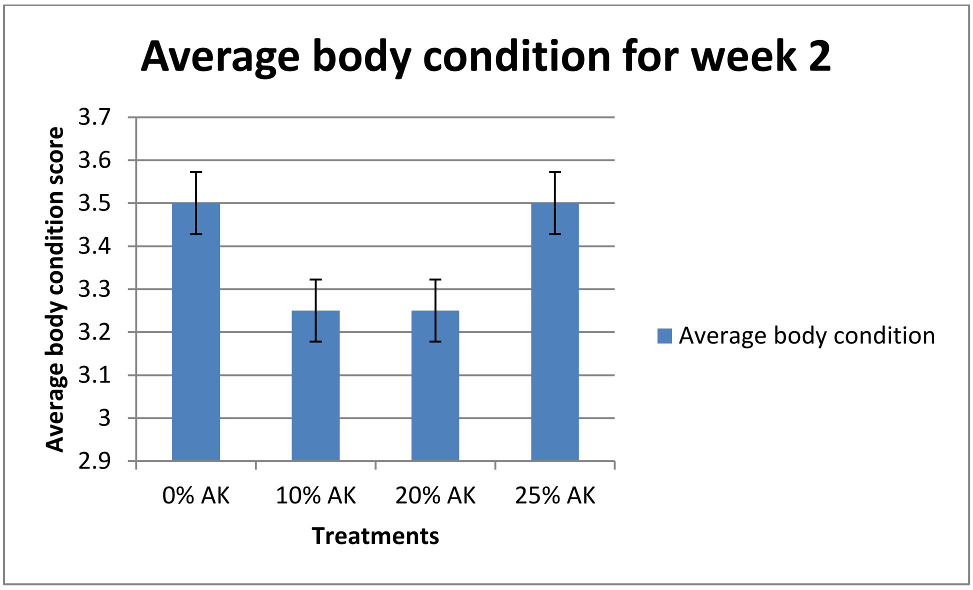


The ANOVA test indicates that there is significant difference between the different treatments ($P<0.05$). Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly body condition score in each treatment are significantly different. The control and 25% *A. Karroo* depicted the high body condition score (3.50). They are both not statistically different from each other. The rest of the treatments showed low body condition score and they are both statistically the same.

Table: 4.13. Shows the body condition score for week 2

Treatments	**N**	**Mean**	**Std. Error**
0% AK	4	3.50	0.289
10% AK	4	3.25	0.479
20% AK	4	3.25	0.250
25% AK	4	3.50	0.289
Mean	16	3.38	0.155

The table above shows the weekly average body condition score for the goats assigned in each treatment. Each treatment was assigned four goats, 2 male and 2 female. The average body condition score are slightly varying from treatment to treatment.

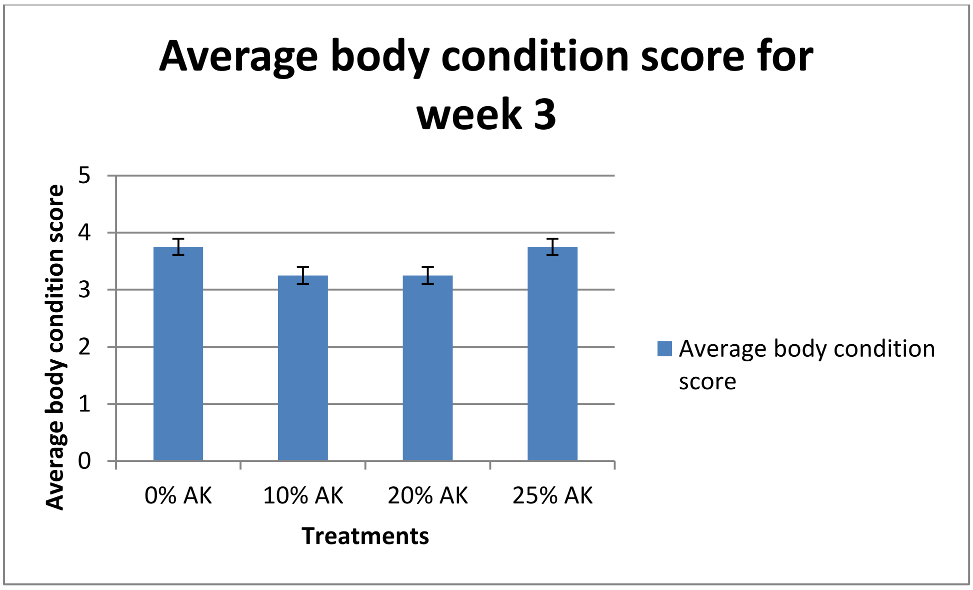


The ANOVA test indicates that there is significant difference between the different treatments (P<0.05). Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly body condition score in each treatment are significantly different (3.50). The control and 25% *A. Karroo* depicted the high body condition score. They are both not statistically different from each other. The rest of the treatments showed low body condition score and they are both statistically the same.

Table: 4.14. Shows the body condition score for week 3

Treatments	**N**	**Mean**	**Std. Error**
0% AK	4	3.75	0.479
10% AK	4	3.25	0.479
20% AK	4	3.25	0.250
25% AK	4	3.75	0.250
Mean	16	3.50	0.183

The table above shows the weekly average body condition score for the goats assigned in each treatment. Each treatment was assigned four goats, 2 male and 2 female. The average body condition score are slightly varying from treatment to treatment.

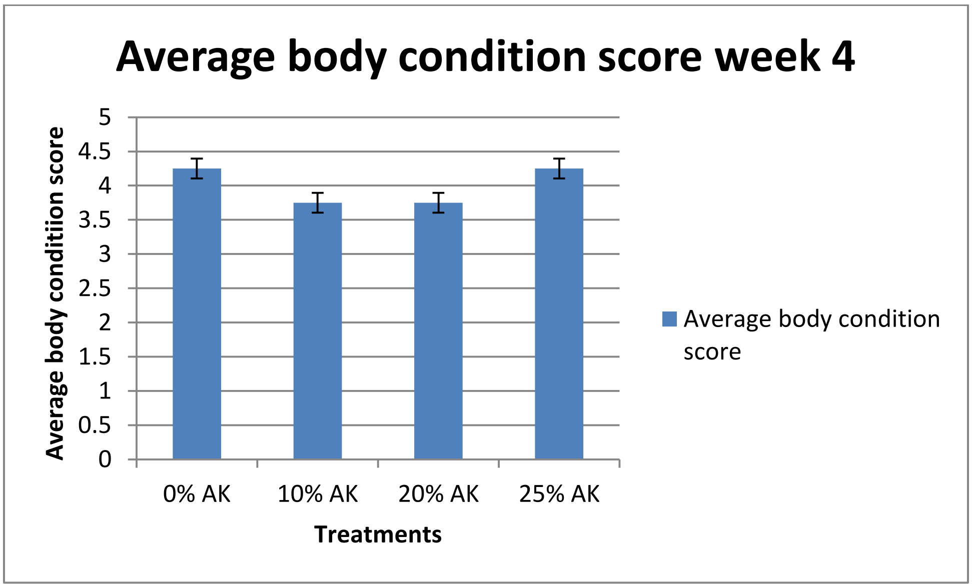


The ANOVA test indicates that there is significant difference between the different treatments ($P<0.05$). Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly body condition score in each treatment are significantly different. The control and 25% *A. Karroo* depicted the high body condition score (3.75) but they are not statistically different from the rest of the treatments. Both the 10 and 20% *A. Karroo* showed low Body condition score.

Table: 4.15. Shows the body condition score for week 4

Treatments	N	Mean	Std. Error
0% AK	4	4.25	0.479
10% AK	4	3.75	0.289
20% AK	4	3.75	0.479
25% AK	4	4.25	0.000
Mean	16	3.88	0.180

The table above shows the weekly average body condition score for the goats assigned in each treatment. Each treatment was assigned four goats, 2 male and 2 female. The average body condition score are slightly varying from treatment to treatment.

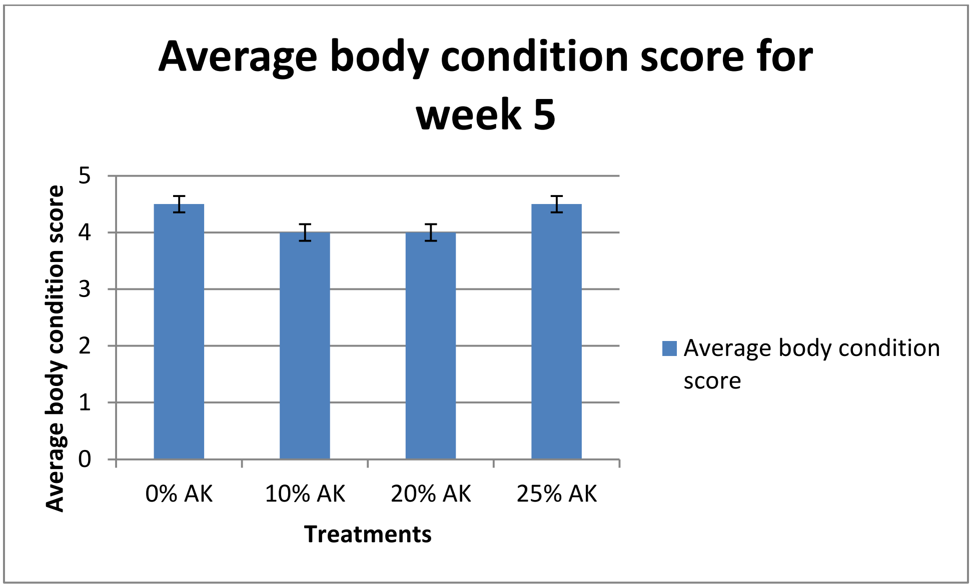


The ANOVA test indicates that there is a significant difference between the different treatments ($P<0.05$). Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly body condition score in each treatment are significantly different. The control and 25% *A. Karroo* depicted the high body condition score (4.25) and are both statistically the same. Both the 10 and 20% *A. Karroo* showed low Body condition score.

Table: 4.16. Shows the body condition score for week 5

Treatments	**N**	**Mean**	**Std. Error**
0% AK	4	4.25	0.479
10% AK	4	4.00	0.408
20% AK	4	4.00	0.408
25% AK	4	4.50	0.289
Mean	16	4.19	0.188

The table above shows the weekly average body condition score for the goats assigned in each treatment. Each treatment was assigned four goats, 2 male and 2 female. The average body condition score are slightly varying from treatment to treatment.

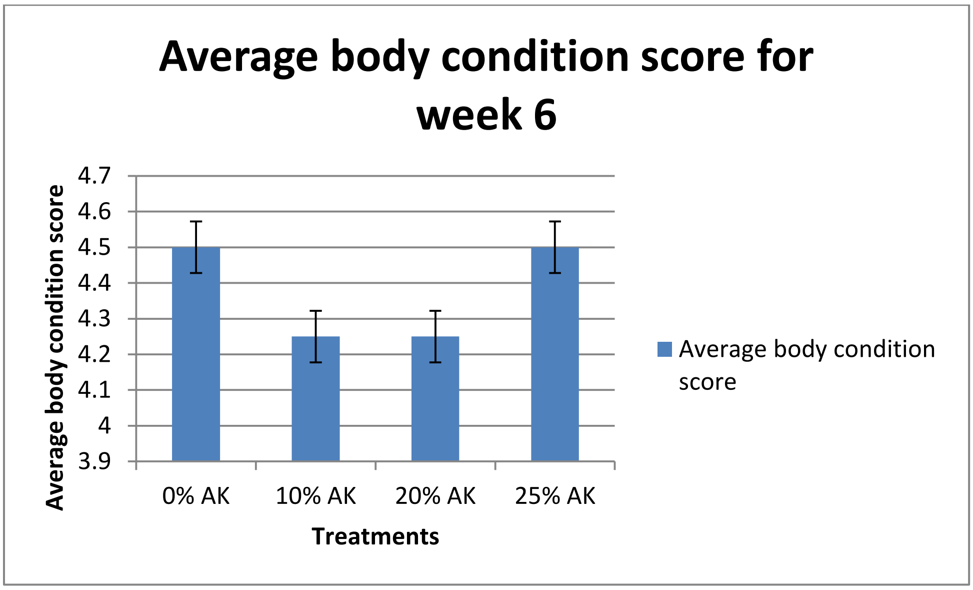


The ANOVA test indicates that there is significant difference between the different treatments (P<0.05) Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly body condition score in each treatment are not significantly different. The control and 25% *A. Karroo* depicted the high body condition score (4.5) and are both statistically the same. Both the 10 and 20% *A. Karroo* showed low Body condition score.

Table: 4.17. Shows the body condition score for week 6

Treatments	N	Mean	Std. Error
0% AK	4	4.50	0.289
10% AK	4	4.25	0.479
20% AK	4	4.25	0.250
25% AK	4	4.50	0.289
Mean	16	4.38	0.155

The table above shows the weekly average body condition score for the goats assigned in each treatment. Each treatment was assigned four goats, 2 male and 2 female. The average body condition score are slightly varying from treatment to treatments.

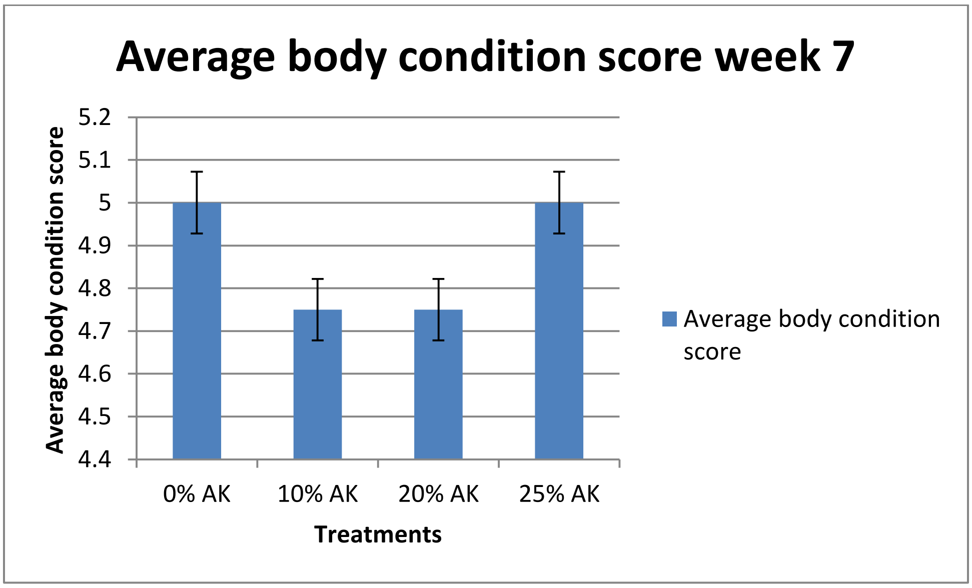


The ANOVA test indicates that there is significant difference between the different treatments (P<0.05). Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly body condition score in each treatment are significantly different. The control and 25% *A. Karroo* depicted the high body condition score (4.5) and are both statistically the same. Both the 10 and 20% *A. Karroo* showed low Body condition score

Table 4.18 shows the body condition score for week 7

Treatments	N	Mean	Std. Error
0% AK	4	5.00	0.577
10% AK	4	4.75	0.289
20% AK	4	4.75	0.479
25% AK	4	5.00	0.289
Mean	16	4.69	0.198

The table above shows the weekly average body condition score for the goats assigned in each treatment. Each treatment was assigned four goats, 2 male and 2 female. The average body condition score are slightly varying from treatment to treatments.

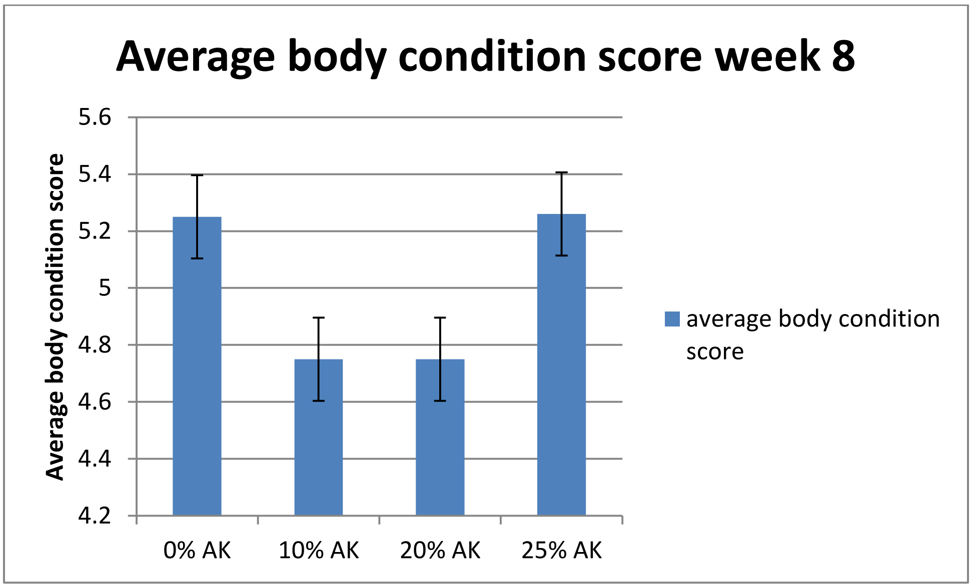


The ANOVA test indicates that there is significant difference between the different treatments ($P<0.05$). Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly body condition score in each treatment are significantly different. The control and 25% *A. Karroo* depicted the high body condition score (5.0) and are both statistically the same. Both the 10 and 20% *A. Karroo* showed low Body condition score.

Table: 4.19. Shows the body condition score for week 8

Treatments	**N**	**Mean**	**Std. Error**
0% AK	4	5.25	0.479
10% AK	4	4.75	0.479
20% AK	4	4.75	0.479
25% AK	4	5.00	0.408
Mean	16	4.94	0.213

The table above shows the weekly average body condition score for the goats assigned in each treatment. Each treatment was assigned four goats, 2 male and 2 female. The average body condition score are slightly varying from treatment to treatments.



The ANOVA test indicates that there is a significant difference between the different treatments (P<0.05). Since the p-value is less than the significant level (0.05) we conclude that the means of the average weekly body condition score feed in each treatment are significantly different, therefore the hypothesis which says tanniferous *A. karoo* leaf meal level of supplementation at finisher stage has no effect on body condition score could be rejected. The control and 25% *A. Karroo* depicted the high body condition score (5.0) and are both statistically the same. Both the 10 and 20% *A. Karroo* showed low Body condition score.

CHAPTER 5

DISCUSSION

5.0. Growth performance of Boer goats when Lucerne and pellets are replaced with *Acacia karroo* under Namibian weather conditions

5.1. Feed analyses results

The determined crude protein content of *A. karroo* leaf meal was 10.2g per 100g, which is smaller than 120g per kg reported by Ngambi et al. (2009). This is quite high and ideal for supplementation in animal feeds (Makkar, 2003). *A. karroo* leaves contains high concentrations of tannins, predominantly condensed tannins, its high protein contents are best for supplementation in animal feeds, as shown in the study by Makkar (2003), cited in Ngambi et al. (2009). Browse plants such as the Acacia species are reported to be an enormous potential source of protein supplementation (100 to 250 g/kg DM) for ruminants in the tropics (Ngongoni et al., 2007) and can easily meet nutrient requirements, mainly proteins (Aganga et al., 1998; Devendra and Sevilla, 2002; Kahiya et al., 2003; Marume et al., 2012), minerals (Aganga et al., 1998; Mukoboki et al., 2005) and they have antihelmintic properties (Xhomfulana et al., 2009).

Experimental diets (T1, T2, T3 and T4) used to study the effects of adding *A.karroo* leaf meal at different levels on Lucerne and pellets based diets contained 10, 12, 11 and 12ME/MJ/kg energy contents and 18g, 15.4g, 14.9g and 15.2g protein contents, respectively. These diets were formulated, considering the costs of Boer goat diets as well as Namibia's harsh environmental conditions.

5.2. Effects of *A. karroo* leaf meal on average weight and FCR

The present study observed that different *A. karroo* leaf meal levels added to Lucerne and pellets based diets has a significant ($P<0.05$) effect on weight gain and feed conversion ratio (FCR) (g feed/g live weight gain) of Boer goats from 3-5 month of age. This however, supports the results reported by Mapiye et al., 2009; Nyamukanza and Scogings, 2008, that supplementation with browse plants, particularly *A. karroo* leaves, improves the body condition score, slaughter weight and average daily gain.

A. karroo has been reported to contain chemical substances which have anti-helmintic properties (Kahiya et al., 2003; Xhomfulana et al., 2009). Kahiya et al. (2003) reported that goats fed *A. karroo* leaves had lower faecal egg counts and Haemonchus contortus worm counts than the infected control group. These studies demonstrate that supplementing ruminants with *A. karroo* leaves reduces nematode burdens.

Generally, the reduction in nematode burdens in animals consuming browse legumes is attributed to the anti-helmintic activity of condensed tannins (Hoste et al., 2006; Minho and Abdalla, 2007; Xhomfulana et al., 2009). The mechanisms by which condensed tannins counteract effects of gastrointestinal parasites in ruminants are not clear. It has been speculated that direct effects on the parasites, and indirect effects on the host animal, may play a role. The direct effects involve the capacity of condensed tannins to bind with proteins in the rumen (Alonso-Díaz et al., 2008; Hernández-Ordu˜no et al., 2008), intestinal mucosa proteins (Schultz, 1989), cuticle glycoproteins (Hoste et al., 2006) and/or faecal egg proteins of larvae (Niezen et al., 2002). These processes could reduce larval growth and development or inhibit egg hatching, and result in larvae death (Niezen et al., 2002; Hoste et al., 2006).

Assessment of the structure–activity relationships of tannins, and clarification of their metabolic mechanisms in controlling helminths, is invaluable. The antihelmintic indirect effects of condensed tannins have been mainly attributed to the animal's improved resistance and resilience to gastrointestinal nematodes with an increase in digestible protein supply (Minho and Abdalla, 2007). The mode of action at the cellular level remains to be investigated.

H. contortus is a highly pathogenic, blood sucking nematode causing clinical signs of anaemia, oedema (bottle-jaw), diarrhoea and death. When clinical signs are present, H. contortus infection is commonly called haemonchosis, which results in pallor of the mucous membranes and skin (Bowman, 2003). Haemonchosis causes dramatic economic loss. This loss is due to decreased production, cost of prevention and treatment and ultimately death of infected animals.

5.3. Effects of *A. karroo* leaf meal on Feed intake

The present study observed that different *A. karroo* leaf meal levels added to Lucerne and pellets based diets has a significant ($P < 0.05$) effect on feed intake of Boer goats from 3-5 month of age. This however contradict results were obtained by Al-mamary et al., (2001) who found that addition of sorghum grains low in tannins to diets of rabbits didn't change growth rate, feed intake and feed conversion ratio. Similar results were also reported by Diao et al., (1990). These finding are contrary to the finding of Laeurena et al., (1984), Makkar (2003) and Hassen et al., (2003) who found adverse effect of tannins on feed efficiency, growth rate and protein digestibility.

Low inclusion of leguminous leaf meals has been reported to increase intake (D'Mello, 1995; Halimani *et al*., 2005). Further increases of leaf meals have, however, been shown to depress intake. The differences in the intake of animals fed leaf meals could be due to differences in the basal diets used and in the nature of the leaf meal supplements (Halimani, 2005). In addition, other substances have been reported to reduce intake of diets containing leaf meals. These include hydrogen cyanide in Manihot esculenta (Phuc et al., 2000), mimosine and polyphenols in L. leucocephala (Cheverria et al., 2002).

5.4. Effects of *A. karroo* leaf meal on body condition score

The present study observed that different *A. karroo* leaf meal levels added to Lucerne and pellets based diets has a significant ($P<0.05$) effect on body condition score of Boer goats from 3-5 month of age. This however supports the results reported by Aganga et al. (1998) and Nyamukanza and Scogings (2008), reported higher ADG for goats fed *A. karroo* leaves compared to those fed a control diet. The superior performance displayed by ruminants fed dried browse legume leaves is partially credited to a high concentration of CP, its moderate digestibility, and desirable effects of condensed tannins (Rubanza et al., 2007; Mapiye et al., 2009b). Low concentrations of condensed tannins improve protein nutrition by binding to plant proteins in the rumen, thus preventing microbial degradation and increasing amino acid flow to the duodenum to increase absorption of amino acids in the jejunum and ileum (Mueller-Harvey, 2006). This could lead to more protein metabolised into muscle and, consequently, higher slaughter weights and heavier carcasses (Gleghorn et al., 2004).

5.5 Effect of *A. karroo* on Nutrient digestibility

Inclusion of leaf meals tends to lower nitrogen retention and digestibility of nutrients (Laswai *et al.,* 1997; Ly *et al.,* 1998; Cheverria *et al.,* 2002; Phuc *et al.,* 2000). A reduction in dry matter digestibility can result from an increase in the flow of digesta and total tract excretion of nutrients and energy as a result of the higher insoluble fibre content of leguminous leaf meals (Lindberg & Cortova, 1995). Low digestibility of protein may be due to protein being bound by polyphenols and fibre or physically entrapped by fibre in the leaf meals (Phuc *et al.*, 2000). It may also be due to and increase in hindgut fermentation leading to higher loss of bacterial nitrogen or due to enhanced secretion of endogenous protein coupled with reduced degradation and reabsorption of endogenously secreted protein (Jansman *et al.*, 1995; Lindberg & Andersson, 1998). Higher levels of intake of these leaf meals been shown to depress digestibility of nutrients and, at the same time, increase the activity of enzymes that are responsible for detoxification of toxic substances in the body (Halimani *et al.*, 2005).

5.6 Constraints to leaf meal utilisation

Even though chemical composition of leaf meals show some potential feeding value, this value is seldom achieved in practice (D'Mello, 1995). Most leaf meals have high fibre contents and also contain various secondary plant metabolites that interfere with digestion in the animal and in instances are poisonous. These lead to a reduction in animal performance. For example, *L. leucocephala* leaf meal contains mimosine, a non-protein amino acid, which interferes with protein metabolism. In addition, most leaf meals contain polyphenolic compounds that bind proteins and reduce both palatability and digestibility (Cheverria *et al.,* 2002; Halimani *et al.,* 2005). Efforts to use cassava leaf meal as a feed supplement are also constrained by the intrinsic low digestibility of the leaf meal and presence of hydrogen cyanide (Phuc *et al.*, 2000). The fibre fractions of these leaf meals are hardly utilised in pigs (D'Mello, 1995), except, perhaps those pigs where hind gut fermentation is significant, as has been suggested in the indigenous pigs (Kanengoni *et al.*, 2002). The fibre may also lead to lower digestibility of nutrients as some nutrients are bound to or are physically entrapped in the fibre.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

The current study revealed that *A. karroo* supplementation has effect on weight gain, feed intake, FCR and body condition score of Boer goats with the best inclusion rate being 25% because it compared well with the positive control. Supplementing goats with *A. karroo* as an alternative feed source for survival can be practically implemented by resource-limited goat producers since *A. karroo* is easily accessible and the plant species is preferred by goats across seasons.

6.2 RECOMMENDATIONS

In this study, *A. karroo* leaves were used as a feed supplement. Therefore, more studies should be carried out to see the effect of other leguminous plants when used as feed supplements for animals. Repeated feeding trials on a larger scale are recommended before A. *karroo* can be safely used by feed manufacturers. The same research should be done with different breeds of goats.

CHAPTER 7

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Appendixes

Appendix A

Weight Gain

Week 5

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	4	19.6643	4.06541	2.03270	13.1953	26.1333	15.81	23.44
10% AK	4	17.0714	3.38156	1.69078	11.6906	22.4522	12.64	20.73
20% AK	4	18.3143	3.27071	1.63536	13.1099	23.5187	15.10	22.71
25% AK	4	19.0286	.77477	.38739	17.7957	20.2614	17.89	19.57
Total	16	18.5196	2.97339	.74335	16.9352	20.1041	12.64	23.44

Week 6

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	4	20.5714	3.64014	1.82007	14.7792	26.3637	17.09	23.77
10% AK	4	18.0786	3.62901	1.81451	12.3040	23.8531	13.34	22.00
20% AK	4	19.7214	3.40838	1.70419	14.2979	25.1449	16.83	24.46
25% AK	4	20.0500	.82326	.41163	18.7400	21.3600	19.06	21.06
Total	16	19.6054	2.94446	.73612	18.0364	21.1743	13.34	24.46

Week 7

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	4	21.4714	3.85199	1.92599	15.3421	27.6008	17.54	25.06
10% AK	4	18.6857	3.87948	1.93974	12.5126	24.8588	13.89	23.00
20% AK	4	20.1214	2.66827	1.33413	15.8756	24.3672	17.60	23.71
25% AK	4	20.3357	.93091	.46546	18.8544	21.8170	19.49	21.57
Total	16	20.1536	2.93627	.73407	18.5889	21.7182	13.89	25.06

Week 8

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	4	22.3313	4.09407	2.04703	15.8167	28.8458	18.40	26.65
10% AK	4	19.4938	4.18053	2.09026	12.8416	26.1459	14.35	24.05
20% AK	4	21.0750	2.92617	1.46309	16.4188	25.7312	18.50	25.10
25% AK	4	20.7750	1.06654	.53327	19.0779	22.4721	20.00	22.35
Total	16	20.9188	3.14217	.78554	19.2444	22.5931	14.35	26.65

Appendix B

Week 1 average feed intake

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	2	.6939	.01162	.00821	.5896	.7983	.69	.70
10% Ak	2	.6504	.03182	.02250	.3645	.9362	.63	.67
20% AK	2	.7625	.04899	.03464	.3223	1.2027	.73	.80
25% AK	2	.7414	.05253	.03714	.2695	1.2134	.70	.78
Total	8	.7121	.05528	.01954	.6658	.7583	.63	.80

Week 2 average feed intake

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	2	.9996	.01465	.01036	.8680	1.1312	.99	1.01
10% Ak	2	1.0561	.02576	.01821	.8246	1.2875	1.04	1.07
20% AK	2	1.1232	.00960	.00679	1.0370	1.2094	1.12	1.13
25% AK	2	1.0969	.01182	.00836	.9907	1.2031	1.09	1.11
Total	8	1.0690	.05141	.01818	1.0260	1.1119	.99	1.13

Multiple Comparisons

Dependent Variable: Week 2 average feed intake

Tukey HSD

*. The mean difference is significant at the 0.05 level.

(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound

control	10% Ak	-.05643	.01666	.088	-.1242	.0114
	20% AK	-.12357*	.01666	.006	-.1914	-.0558
	25% AK	-.09729*	.01666	.015	-.1651	-.0295
10% Ak	control	.05643	.01666	.088	-.0114	.1242
	20% AK	-.06714	.01666	.052	-.1350	.0007
	25% AK	-.04086	.01666	.208	-.1087	.0270
20% AK	control	.12357*	.01666	.006	.0558	.1914
	10% Ak	.06714	.01666	.052	-.0007	.1350
	25% AK	.02629	.01666	.479	-.0415	.0941
25% AK	control	.09729*	.01666	.015	.0295	.1651
	10% Ak	.04086	.01666	.208	-.0270	.1087
	20% AK	-.02629	.01666	.479	-.0941	.0415

Week 3 average feed intake

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	2	.6558	.04657	.03293	.2374	1.0742	.62	.69
10% Ak	2	.7118	.07829	.05536	.0084	1.4152	.66	.77
20% AK	2	.7611	.00758	.00536	.6930	.8291	.76	.77

25% AK	2	.8163	.05940	.04200	.2826	1.3499	.77	.86
Total	8	.7362	.07566	.02675	.6730	.7995	.62	.86

Week 4 average feed intake

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	2	.7643	.03738	.02643	.4285	1.1001	.74	.79
10% Ak	2	.8182	.05707	.04036	.3054	1.3310	.78	.86
20% AK	2	.8009	.02909	.02057	.5395	1.0622	.78	.82
25% AK	2	.9471	.06970	.04929	.3209	1.5734	.90	1.00
Total	8	.8326	.08312	.02939	.7631	.9021	.74	1.00

Week 5 average feed intake

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	2	.9229	.01717	.01214	.7686	1.0771	.91	.94
10% Ak	2	.9111	.00960	.00679	.8249	.9973	.90	.92
20% AK	2	.9943	.05758	.04071	.4770	1.5116	.95	1.04

25% AK	2	.9727	.01899	.01343	.8021	1.1433	.96	.99
Total	8	.9502	.04395	.01554	.9135	.9870	.90	1.04

Week six average feed intake

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
control	2	.7993	.00707	.00500	.7358	.8628	.79	.80
10% Ak	2	.7827	.00121	.00086	.7718	.7936	.78	.78
20% AK	2	.9107	.07576	.05357	.2300	1.5914	.86	.96
25% AK	2	.8568	.01768	.01250	.6980	1.0156	.84	.87
Total	8	.8374	.06152	.02175	.7859	.8888	.78	.96

Week 7 average feed intake

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	2	.6975	.04596	.03250	.2845	1.1105	.67	.73
10% Ak	2	.6414	.01323	.00936	.5225	.7603	.63	.65
20% AK	2	.6711	.00051	.00036	.6665	.6756	.67	.67
25% AK	2	.7129	.00202	.00143	.6947	.7310	.71	.71

Total	8	.6807	.03424	.01210	.6521	.7093	.63	.73

Week eight average feed intake

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Control	2	1.0100	.03300	.02333	.7135	1.3065	.99	1.03
10% Ak	2	1.0140	.09994	.07067	.1161	1.9119	.94	1.08
20% AK	2	.8867	.05421	.03833	.3996	1.3737	.85	.93
25% AK	2	1.1942	.18974	.13417	-.5106	2.8989	1.06	1.33
Total	8	1.0262	.14452	.05110	.9054	1.1470	.85	1.33

Appendix C

Body condition score

Week 1

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
0% AK	4	3.50	.577	.289	2.58	4.42	3	4
10% AK	4	3.25	.957	.479	1.73	4.77	2	4
20% AK	4	3.00	.816	.408	1.70	4.30	2	4
25% AK	4	3.50	.577	.289	2.58	4.42	3	4
Total	16	3.31	.704	.176	2.94	3.69	2	4

Week 2

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
0% AK	4	3.50	.577	.289	2.58	4.42	3	4
10% AK	4	3.25	.957	.479	1.73	4.77	2	4
20% AK	4	3.25	.500	.250	2.45	4.05	3	4
25% AK	4	3.50	.577	.289	2.58	4.42	3	4
Total	16	3.38	.619	.155	3.05	3.70	2	4

Week 3

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
0% AK	4	3.75	.957	.479	2.23	5.27	3	5
10% AK	4	3.25	.957	.479	1.73	4.77	2	4
20% AK	4	3.25	.500	.250	2.45	4.05	3	4
25% AK	4	3.75	.500	.250	2.95	4.55	3	4
Total	16	3.50	.730	.183	3.11	3.89	2	5

Week 4

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
0% AK	4	4.25	.957	.479	2.73	5.77	3	5
10% AK	4	3.50	.577	.289	2.58	4.42	3	4
20% AK	4	3.75	.957	.479	2.23	5.27	3	5
25% AK	4	4.00	.000	.000	4.00	4.00	4	4
Total	16	3.88	.719	.180	3.49	4.26	3	5

Week 5

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
0% AK	4	4.25	.957	.479	2.73	5.77	3	5
10% AK	4	4.00	.816	.408	2.70	5.30	3	5
20% AK	4	4.00	.816	.408	2.70	5.30	3	5
25% AK	4	4.50	.577	.289	3.58	5.42	4	5
Total	16	4.19	.750	.188	3.79	4.59	3	5

Week 6

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
0% AK	4	4.50	.577	.289	3.58	5.42	4	5
10% AK	4	4.25	.957	.479	2.73	5.77	3	5
20% AK	4	4.25	.500	.250	3.45	5.05	4	5
25% AK	4	4.50	.577	.289	3.58	5.42	4	5
Total	16	4.38	.619	.155	4.05	4.70	3	5

Week 7

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
0% AK	4	5.00	1.155	.577	3.16	6.84	4	6
10% AK	4	4.50	.577	.289	3.58	5.42	4	5
20% AK	4	4.75	.957	.479	3.23	6.27	4	6
25% AK	4	4.50	.577	.289	3.58	5.42	4	5
Total	16	4.69	.793	.198	4.26	5.11	4	6

Week 8

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
0% AK	4	5.25	.957	.479	3.73	6.77	4	6
10% AK	4	4.75	.957	.479	3.23	6.27	4	6
20% AK	4	4.75	.957	.479	3.23	6.27	4	6
25% AK	4	5.00	.816	.408	3.70	6.30	4	6
Total	16	4.94	.854	.213	4.48	5.39	4	6

Appendix D

Initial and final body measurement of Boer goat kids

Initial body measurements				
	n	Mean	Maximum	Minimum
Body length	16	48.06 ±1.05	54.0	39.0
Hearth girth	16	24.84 ± 0.35	29.0	23.0
Height at withers	16	53.31±1.15	59.0	44.0
Hearth width back of withers	16	13.13 ± 0.40	15.9	10.5
Hearth depth	16	19.99 ± 0.31	22.0	17.5
Legs girth	16	44.11 ± 0.67	47.0	39.0
Final body measurement				
Body length	16	20.92 ± 0.79	26.65	14.35
Hearth girth	16	68.62 ± 1.64	79.0	60.0
Height at withers	16	59.23 ± 0.81	47.0	39.0
Hearth width back of withers	16	14.92 ± 0.42	19.0	13.0
Hearth depth	16	23.72 ± 0.61	28.0	20.0
Legs girth	16	57.35 ± 1.18	68.0	49.5