CHAPTER 1

INTRODUCTION

1.1 Background

The broiler chicken industry is an important source of animal protein in Limpopo province in comparison with cattle and pigs (Boer *et al*., 2001). Small poultry holdings provide supplementary food, income and employment, and contribute to poverty alleviation in South Africa (Sonaiya, 1999).

Excess body fat deposition in broiler chickens 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 poultry meat via dietary means has become important (Hargis & Elswyk, 1993; Sacks, 2002).

1.2 Motivation

Rural poultry production can play an important role in poverty alleviation and in the supply of quality protein to rural people. Approximately 20 % of protein consumed in developing countries originates from chicken meat (Pedersen, 1998). Over the last century, the amount and proportion of animal fat in human diets have increased in many societies. These increases have been associated with the occurrence of cardiovascular diseases (Liechtenstein, 1999; Katan, 2000). In many societies, coronary heart diseases and arteriosclerosis are related to the dietary intake of cholesterol and saturated fatty acids, and are among the most important causes of human mortalities (Sacks, 2002).

It is widely acknowledged that there is a need for low intakes of cholesterol and saturated fats (Evans *et al.,* 2002). The control of lipid deposition in broiler chickens aimed at efficient lean poultry meat production is of current interest (Fisher & McNab, 1997). Tannins have been associated with reduced carcass fat content in grazing lambs, relative to lambs grazing white clover only (Purchase & Keogh, 1984). However, the effects of tannins on broiler chicken fat content are not known. Therefore, the present study was aimed at determining whether ingestion of tannins at finisher stage would reduce fat content in broiler chickens.

1.3 Aim and objectives

1.3.1 Aim

The aim of this study was to determine the effect of *Acacia karroo* leaf meal level of supplementation on fat deposition in broiler chickens.

1.3.2 Objectives

The objectives of this study were to:

1. Determine the effect of level of tanniniferous *Acacia karroo* leaf meal supplementation at finisher stage on feed intake, digestibility, live weight, feed conversion ratio, mortality and carcass characteristics of male and female Ross 308 broiler chickens.
2. Determine the effect of dietary energy level at finisher stage on feed intake, digestibility, live weight, feed conversion ratio, mortality and carcass characteristics of male and female Ross 308 broiler chickens.

3. Determine interactive effects of level of tanniniferous *Acacia karroo* leaf meal supplementation and dietary energy level at finisher stage on feed intake, digestibility, live weight, feed conversion ratio, mortality and carcass characteristics of male and female Ross 308 broiler chickens.
4. Determine the relationships between *Acacia karroo* leaf meal level of supplementation and short-term biological responses of male and female Ross 308 broiler chickens.

1.4 Hypotheses

Hypotheses of the study were:

1. Tanniniferous *Acacia karroo* leaf meal level of supplementation at finisher stage has no effect on feed intake, digestibility, live weight, feed conversion ratio and mortality but affects carcass characteristics of male and female Ross 308 broiler chickens.
2. Dietary energy level at finisher stage has no effect on feed intake, digestibility, live weight, feed conversion ratio, mortality but affects carcass characteristics of male and female Ross 308 broiler chickens.
3. Tanniniferous *Acacia karroo* leaf meal level of supplementation and dietary energy level at finisher stage have no interactive effect on feed intake, digestibility, live weight, feed conversion ratio and mortality but affect carcass characteristics of male and female Ross 308 broiler chickens.
4. There are no relationships between *Acacia karroo* leaf meal level of supplementation and short-term biological responses of male and female Ross 308 broiler chickens.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In broiler chickens, extensive genetic selection towards a fast-growing chicken has led not only to a dramatic shortening of the growing period, but also to excessive carcass fatness, which consequently lowers meat yield and feed efficiency. In addition, fat deposition has become a serious threat in the breeder flocks since obesity also leads to infertility (Friedman-Einat *et al.*, 2003). Excessive fatness is one of the undesirable consequences of selection for increased growth of modern broiler chickens. Accumulation of fat in carcasses of broiler chickens represents waste product to consumers who are increasingly concerned about the nutritional and health aspects of their food (Mahmoud & Mihaly, 1998). Fat amount, fat quality and cholesterol content in food are important consideration when the relationships between fat and the risk of some cardiovascular diseases and cancer are evaluated (Ahn *et al*., 1995; Cherian & Wolfe., 1996).

2.2 Tannins

Tannins are water-soluble phenolic metabolites of plants with a molecular weight of >500 and with the ability to precipitate gelatine and other proteins from aqueous solution (Mehansho *et al*., 1987). Tannins are a very complex group of plant secondary metabolites, which are soluble in polar solution and are distinguished from other polyphenolic compounds by their ability to precipitate proteins (Silanikove *et al*., 2001). Tannins are found in approximately 80% of woody and 15% of herbaceous dicotyledon species. They can occur at high levels in some forages and feeds (Bryant *et al*., 1992).

Tannins, because of their protein-binding properties, are known to be strongly astringent. This astringency appears to be the major cause of reduced food intake in mammalian herbivores. There is some controversy, however, over whether reduced food intake is a result of the toxic nature of tannins. Singleton (1981) considers it unfair to consider the effects of tannins on feed intake as toxicity, since the result is due to a failure to consume, rather than to consumption itself. On the other hand, Provenza *et al*. (1991) suggested that mammals might reject tannin-containing plants because they cause internal malaise.

Severe growth depression can be a consequence of reduced feed intake, and has been shown to occur in rats and chicks when fed with tannin-containing diets (Alledredge, 1994). When tannins complex with protein in an animal's gut, they are believed to be responsible not only for growth depression, but also for low protein digestibility and increased faecal nitrogen concentrations. Thus, once they have been consumed, their adverse effects, again, seem to be related to their binding of dietary protein (Alldredge, 1994). There is evidence to suggest that enzymatic proteins, as well as other endogenous proteins, comprise a considerable portion of excreted nitrogen when animals are fed tannins (Alledredge, 1994). When endogenous proteins are lost in this manner, the animal may incur a deficiency in one or more essential amino acids. McKersie and Brown (1997) reported that the most widely recognized property of condensed tannins is their capacity to strongly and selectively bind to proteins and other macromolecules, such as cell wall carbohydrates and starch, due to their high level of phenolic hydroxyl groups.

During breakdown of foliage, such as chewing by animals, condensed tannins react with and precipitate plant proteins by hydrogen bonding to form complexes that are stable and insoluble in the rumen but unstable and release protein in the small intestines (McKersie and Brown, 1997).

2.2.1 Types of tannins

There are two types of soluble tannins present in a large number of plant species. These are the hydrolysable tannins (HTs) and the non-hydrolysable or condensed tannins (CTs). Hydrolysable tannins are characterized by a central carbohydrate core with a number of phenolic carboxylic acids bound by ester linkages. Condensed tannins have no carbohydrate core, but rather they are derived from the condensation of flavonoid precursors without participation of enzymes. Condensed tannins are more widely distributed in higher plant species than the hydrolysable variety and are thought to be more active in precipitating proteins. Condensed tannins vary from different multipurpose trees (Table 2.1) and the variation may be due to differences in the age of leaves and plants at harvest (Lege *et al*., 1992, Wolfson *et al*., 1993).

Table 2.1. Proanthocyanidins (CT) from acacia trees

Authors	Condensed tannins	Type of legume species
Balogun *et al*. (1998)	4.27 (% DM)	*Acacia currassavica*
Maasdorp *et al*. (1999)	11.35 (Au_{550nm} / g sample)	*Acacia boliviana*
Dube *et al*. (2001)	2.01 (A_{550}, g sample)	*Acacia karoo*
	0.19 (A_{550}, g sample)	*Acacia nilotica*
	1.47 (A_{550}, g sample)	*Acacia tortilis*
	0.04 (A_{550}, g sample)	*Acacia senegal*
	1.36 (A_{550}, g sample)	*Acacia erioloba*
	1.36 (A_{550}, g sample)	*Acacia albida*
Mashamaite (2004)	0.37 (% DM)	*Acacia nilotica*
	4.07 (% DM)	*Acacia tortilis*
	4.52 (% DM)	*Acacia karroo*

2.2.1.1 Condensed tannins

Condensed tannins are naturally occurring compounds found in a number of different plants, including some pasture species (Idso & Idso, 2002). Condensed tannins comprise a group of polyhydroxyflavan-3 oligomers and polymers linked by carbon-carbon bonds between flavanol subunits. The reactivity of proanthocyanidins with molecules of biological significance has important nutritional and physiological consequences. Their multiple phenolic hydroxyl groups lead to the formation of complexes with proteins (Hagerman *et al*., 1998; Harbone, 1998). Proanthocyanidins in

feeds for ruminants may interfere with intake and digestion of the feed in which they occur (Dube *et al*., 2001). They are having a negative effect on protein metabolism and

decrease palatability of feeds at high levels (Barry & Manley, 1986) but at very low levels most are beneficial (Foo *et al*., 1996). At moderate concentrations, however, condensed tannins can be beneficial to ruminant livestock production. Among some of the beneficial effects, condensed tannins complex with soluble proteins in the rumen and permit subsequent absorption of amino acids in the lower digestive tract (Barry & Manley, 1986), thereby facilitating ruminal escape protein utilization (Waghorn *et al.,* 1999). Condensed tannins can benefit ruminants by reducing protein losses to degradation in the rumen and improving the flow of protein to the small intestines, and some field trials have indicated an improved performance attributable to the condensed tannins in diets fed to sheep (Douglas *et al.,* 1995).

In Lotus species, condensed phenolic contents up to 25 g/kg DM appear to have little effect on rumen carbohydrate digestion but concentrations between 25 and 100 g/kg DM reduce carbohydrate digestion in the rumen in a dose dependent manner (Barry & Manley, 1986). Barry *et al.* (1986) observed increased levels of growth hormone and their results suggested an increase in the ratio of lipolysis to lipogenesis. The presence of condensed tannin has been associated with reduced carcass fat content in lambs grazing *L. pedunculutas* (Purchas & Keogh, 1984) and *H. coronarium* (Terrill *et al*., 1992). However, in lambs grazing *L.corniculatus*, Wang *et al*. (1996) found no difference in carcass fatness. A possible explanation for this reduction of fatness has been suggested by Barry *et al.* (1986) who found a lower level of growth hormone (GH) in lambs when diets were sprayed with Polyethylene glycol. Growth hormone increase N retention and reduce fat deposition, with an increase in fat turn over. The reason for the higher level in

plasma GH has been explained with a possible inactivation of gut wall proteins by CT. However, Waghorn *et al*. (1994) did not find any difference in the GH titre in lambs fed *L.pedunculatus* with or without PEG. In trials conducted to compare two sorghum strains with different content of CT, lambs fed with the strain containing the higher level of CT showed a meat lighter in colour (Priolo & Salem, 2002).

2.2.2 Hydrolysable tannins

Hydrolysable tannins are esters of a sugar usually glucose and a phenolic acid such as gallic acid in gallotannins. They are known to be toxic to ruminants (Dollahite *et al*., 1962; Shi, 1988). Because of their toxicity, they have received limited attention in animal nutrition studies. Recent studies show that even where they are not toxic, hydrolysable tannins may have significant effect on animal nutrition because they have inhibitory effect on various enzymes (Yoshida *et al*., 2000). The amount and type of tannins synthesized by plants vary considerably depending on plant species, stage of development and environmental condition.

2.3 Mode of action of tannins in livestock

Tannins form soluble and insoluble and sometimes irreversible complexes with proteins, digestive enzymes and possibly starch in the digestive tract of pigs and poultry. Sorghum tannins may bind and precipitate at least 12 times their own weight of protein (Jansman, 1993). Formation of these complexes increases with molecular size of the tannins and inhibit enzymatic breakdown of protein and can increase endogenous amino acid loss. Results of in vitro enzyme assays with tannins do not necessarily mimic reactions in the digestive tract because of the special conditions in *in vivo* digestion (Butler, 1992).

Tannins can increase the size of the parotid glands and damage the mucosal lining of the gastro intestinal tract of chickens, but to a lesser extent in the laboratory rat (Oritz *et al*., 1994) and with much less evidence for pigs. Differences between pigs and poultry in their tolerance for foodstuffs rich in tannins may be due to the very few taste buds (twenty four) in the mouth of chickens compared to the high number (15 000) in the mouth of pigs (Moran, 1982).

Tannins are also found in many poultry foodstuffs such as sorghum, millet, barley and faba beans. Adverse effects of tannins on food palatability and consumption, feed efficiency, growth rate and digestibility of components such as proteins, carbohydrates, lipids and minerals have been repeatedly reported (Laurena *et al*., 1984; Longstaff & McNab, 1991a; Makkar, 2003; Hassan *et al*., 2003; Kim & Miller, 2005). There are also a number of reports on *in vitro* and/or *in vivo* effects of tannins on digestive enzymes (Van Der Poel *et al*., 1992; Lizardo *et al*., 1995; Helsper *et al*., 1996). Although there are some indications on the influence of tannins on the increase in excretion of salivary and intestinal muco-proteins, bile acids, and hypersection of enzymes and endogenous loss of minerals in animals and poultry, report on the possible effect of these anti-nutrients on the endogenous losses of amino acids in poultry are uncommon (Horigome *et al*., 1988; Karasov *et al*., 1992; Mansoori & Acamovic, 1996, 1998 and 2000). Longstaff & McNab (1991b) reported that, chicks fed with diets containing faba beans hulls, that are high in condensed tannins had a poor apparent digestibility of amino acids, particularly

methionine and cystine, probably because of an increased excretion of inactivated enzymes and glycoproteins of the gastrointestinal mucosa. Studies on the effects of condensed tannins have given equivocal results. Flores *et al.* (1994) concluded that there was a negative effect of tannins on starch digestibility in three week old chickens. The extent of the depression depended on the quantity of tannins ingested. With young pigs there was no difference in starch digestibility on diets with faba beans of high and low condensed tannin contents.

Maize is the most commonly used grain source for monogastric animals in many countries due to its known nutritional value and stable composition. However, low tannin sorghums have the feeding values for monogastric animals similar to those of maize (Brand *et al.*, 1992; Douglas *et al*., 1993). Leeson & Summers (1991) stated that low tannin feeds offer an excellent alternative in diets for the production of non-pigmented poultry products. Feeds high in tannins also have a potential to greatly reduce the speed of meat spoilage (Carpenter *et al*., 2007; Vista *et al*., 2007). The production of bird proof (high tannin) sorghum, however, posses nutritional problems when the grain is subsequently incorporated into monogastric feeds (NRC, 1994). Growth studies performed with pigs (sorghum was compared with maize as an alternative grain source) showed that pigs being fed with low tannin sorghum could perform as well as pigs being fed maize (Kemm *et al*., 1984; Brand *et al*., 1992). Diao *et al.* (1990) indicated that broiler chicks can tolerate up to 0.48 % sorghum tannin in the diets and in the later four weeks could tolerate up to 0.64 % sorghum tannin without any adverse effect on weight

gain, feed efficiency, dressing percentage, total serum lipid, cholesterol and glutamatepyruvate transaminase levels.

Feeding a sorghum diet to chicks could reduce the yellow pigment on their beaks and legs. It has been demonstrated that when tannins or tannin containing materials are administered orally to chickens, endogenous losses are increased substantially, presumably a result of interaction between the tannin and epithelial tissue within the gastrointestinal tract (GIT) and also the microflora within the GIT (Muhammed *et al*., 1994; Mansoori & Acamovic, 1998; Bento *et al*., 2005). This interaction is likely to account, at least in part, for the invariable reduction in apparent digestibility coefficients of nitrogen and amino acids, and metabolisable energy found in animals that consume tannins. It is widely accepted that low tannin sorghums can be used in broiler chicken diets without any adverse effects on performance of the birds (Lucbert & Castaing, 1986). These authors stated that the nutritional value of sorghum with tannin content of lower than 10 g/kg was similar to that of maize. Pour-Reza & Edriss (1997) confirmed the results. These showed that all the dietary maize could be replaced by low tannin sorghum as indicated in Table 2.2

Table 2.2 Performance of chicks fed on diets with low or high tannin varieties at different inclusion levels (Pour-Reza and Edriss, 1997).

	Dietary treatment				
Variables	Maize	50/50 maize/ sorghum (low tannin)	Sorghum (low tannin)	50/50 maize and sorghum (high tannin)	Sorghum (high tannin)
Tannin content	0	1.16	2.32	2.61	5.22
Tannin intake (g)	0	6.9	13.5	19.5	29.3
Live weight gain (g)	1968	1988	1913	1973	1866
Feed intake (g) (7-49 days)	3713	3983	3918	3767	3792
Feed conversion ratio (g/g)	1.89	2.0	2.04	1.96	2.04

Armstrong *et al.* (1974) reported that the presence of tannins in some cultivars of sorghum has been associated with depression of growth rate, feed intake, metabolisable energy, protein digestibility and also with leg abnormalities in chicks. Even though tannins are known as anti-nutritional factors, in some instances they tend to be useful because they can also act as anti-microbial factors. They have been shown to increase nitrogen utilization in sheep and to have antihelminthic effects in sheep (Waghorn *et al*., 1994a). Tannins added in ruminant food lower body mass (Buchsbaum *et al*., 1984), reduce protein availability (Robbins *et al*., 1987) and increase excreta nitrogen concentration (Bernays & Butler, 1989).

The leaves and stems of *Lotus pedenculatus* contain condensed tannins, which on disintegration of the plant material, such as during chewing, render the forage proteins insoluble (Ross & Jones, 1974). The presence of condensed tannins therefore makes lotus a non-bloating legume (Ross & Jones, 1974) and at 15 g/kg DM increases duodenal protein flow by reducing plant-protein degradation in the rumen (John & Lancashire, 1982). Condensed tannins seem to have different effects on wool growth depending on the concentration. Wool growth has a direct correlation with protein utilization. At low concentrations, condensed tannins seem to increase wool growth (Terrill *et al.*, 1992; Douglas *et al.*, 1995). Barry (1985) found that oral polyethylene glycol (PEG) administration in sheep fed *Lotus pedunculutus* tended to increase wool growth. This was due to higher level and activity of tannins of *L. pedunculatus*. On addition of PEG, the adverse effects of these tannins were alleviated, leading to the increased voluntary feed intake and to a possible increase of growth hormone (GH) titre. In ewes rearing twin lambs, Wang *et al*. (1996) found that CT from *L. corniculatus* increased milk yield, protein and lactose percentage, reducing fat percentage. An experiment designed to evaluate the specific effect of carob pulp CT on lamb growth and meat quality, showed that when the effects of CT from carob pulp are eliminated by PEG supply, Comisana lamb longissimus muscle was significantly darker.

2.4 Dietary energy levels on performance and carcass composition of broiler chickens

Energy in broiler chickens is needed for maintenance and growth of body tissues, vital metabolic activities and maintenance of normal body temperature (Scott *et al*., 1982).

Broiler chickens eat primarily to satisfy their energy requirements (Scott *et al*., 1982; Reddy, 2000). Therefore, diets with higher energy concentration will have lower intake and those with lower energy concentration will have higher feed intake (Macleod, 1991; Leeson, 1996). Yolsin *et al*. (1990) and Holsheimer & Veerkamp (1992) reported that high energy diets significantly increased absolute carcass weight and yield of abdominal fat, however, carcass part weights were not influenced by dietary energy. Also, relative abdominal fat weight increased linearly with increments in dietary energy. Summers *et al*. (1992) found that increasing dietary energy from 11.02 to 12.75 MJ ME/kg DM diet resulted in male broiler chickens having a significantly higher percentage of fat and a lower percentage of protein. In addition, Waldroup *et al.* (1990) found that even male chickens fed high energy diet series had significantly higher dressing percentages than females fed the low energy diet series.

Since carcass fat deposition can be altered through modifying the energy intake of the broiler chickens (Summers & Leeson, 1984; Leeson *et al*. 1996) it seems reasonable that some positive effects may be obtained by reducing the energy level in broiler diets fed during the growing and finishing periods when the birds consume the major portion of their overall feed consumption.

2.5 Summary

Excessive fatness is one of the undesirable consequences of selection for increased growth of modern broiler chickens. In addition to optimizing growth rate and feed utilization, there is ongoing demand to maximize growth of lean tissue and minimize the undesirable fat accumulation in broiler chickens at marketing age. Tanniniferous feeds are widely used in animal feeding and there is some indication that they can reduce fat content in animals. However, no such studies have been done in chickens.

CHAPTER 3
MATERIALS AND METHODS

3.1 Study area

This experiment was conducted at the University of Limpopo Experimental farm, Limpopo Province, South Africa. The farm is located 10 km northwest of the Turfloop Campus. The ambient temperatures around this area are above 32 °C during summer and around 25 °C or lower during the winter season. Average annual rainfall is between 446.8 and 468.4 mm. This study was conducted between October and December, 2006.

3.2 The grower feeds

The experimental diets were purchased from Zet_B Feeds, Louis Trichardt. The company had been asked to formulate two grower diets, a low energy diet (13.2 MJ ME /kg DM) and a high energy diet (13.8 MJ ME /kg DM). Both diets were formulated to contain 190 g CP per kg DM.

3.3 Foliage material

Acacia karroo leaves were used as a supplement in the experiment. Leaves were hand-harvested early each morning for one week at the University of Limpopo main campus in May, 2006. The leaves were then shade dried and stored indoors for 14 days prior to grinding. The dried leaves were ground, using a 2 mm screen, and stored in air-tight bags until needed for feeding.

3.4 Experimental procedure, dietary treatments and designs

Three hundred and sixty, 21-day old Ross 308 broiler chickens were used in the experiment. The chickens had been on a commercial starter feed (NTK, Polokwane) before commencement of the experiment. The chickens were assigned to twelve dietary treatments, each with three replications and each replication having ten birds. Thus, a total of 36 pens were used. The birds were offered *ad libitum* feed and fresh water throughout the experiment. A 2 (Sex) x 2 (Energy levels) x 3 (Tanniniferous acacia leaf meal levels) factorial arrangement in a complete randomized design (SAS, 1998) was used. The experimental treatments were as follows:

$S_1E_1T_0$: Male broiler chickens fed low energy (13.2 MJ ME /kg DM) diet without tanniniferous *Acacia karroo* leaf meal supplementation.

$S_1E_1T_1$: Male broiler chickens fed a low energy (13.2 MJ ME /kg DM) diet supplemented with 9 g tanniniferous *Acacia karroo* leaf meal per kg diet.

$S_1E_1T_2$: Male broiler chickens fed a low energy (13.2 MJ ME /kg DM) diet supplemented with 12 g tanniniferous *Acacia karroo* leaf meal per kg diet.

$S_1E_2T_0$: Male broiler chickens fed a high energy (13.8 MJ ME /kg DM) diet without tanniniferous *Acacia karroo* leaf meal supplementation.

$S_1E_2T_1$: Male broiler chickens fed a high energy (13.8 MJ ME /kg DM) diet supplemented with 9 g tanniniferous *Acacia karroo* leaf meal per kg diet.

$S_1E_2T_2$: Male broiler chickens fed a high energy (13.8 MJ ME /kg DM) diet supplemented with 12 g tanniniferous *Acacia karroo* leaf meal per kg diet.

$S_2E_1T_0$: Female broiler chickens fed a low energy (13.2 MJ ME /kg DM) diet without tanniniferous *Acacia karroo* leaf meal supplementation.

$S_2E_1T_1$: Female broiler chickens fed a low energy (13.2 MJ ME /kg DM) diet supplemented with 12 g tanniniferous *Acacia karroo* leaf meal per kg diet.

$S_2E_1T_2$: Female broiler chickens fed a low energy (13.2 MJ ME /kg DM) diet supplemented with 12 g tanniniferous *Acacia karroo* leaf meal per kg diet.

$S_2E_2T_0$: Female broiler chickens fed a high energy (13.8 MJ ME /kg DM) diet without tanniniferous *Acacia karroo* leaf meal supplementation.

$S_2E_2T_1$: Female broiler chickens fed a high energy (13.8 MJ ME /kg DM) diet supplemented with 9 g tanniniferous *Acacia karroo* leaf meal per kg diet.

$S_2E_2T_2$: Female broiler chickens fed a high energy (13.8 MJ ME /kg DM) diet supplemented with 9 g tanniniferous *Acacia karroo* leaf meal per kg diet.

3.5 Data collection

The mean feed intake was measured daily by subtracting the weight of feed refusals from the feed offered per day, and the difference was divided by the total number of birds in each pen. Initial live weights of the chickens were measured at the start of the experiment. Mean live weight of the chickens was taken daily by weighing birds in each pen and the total weight was then divided by the total number of birds in the pen. These live weights were used to calculate growth rate. Feed conversion ratio was calculated as the total amount of feed consumed divided by the weight gain of live birds.

Digestibility measurements were carried out when the birds were between 35 and 42 days of age. This was done in specially designed metabolic cages fitted with excreta collection trays, separate watering and feeding troughs. Two birds were randomly selected from each replicate and transferred to metabolic cages. Birds were allowed to adapt for a period of three days in their crates prior to collection of excreta and feed refusals. After that period excreta was collected from each cage and stored at -15 °C during the collection period. Apparent digestibility (AD) of nutrients was calculated as follows:

$$AD\ (\%) = \frac{(\text{Amount of nutrient ingested} - \text{amount of nutrient excreted})}{(\text{Amount of nutrient ingested})} \times 100$$

At 42 days old, the remaining birds per pen were weighed on an electronic weighing scale and then slaughtered. After slaughtering, carcass weight of an individual bird was measured. Dressing percentage was determined. Dressing percentage was equal to carcass weight divided by live weight and then multiplied by one hundred. The dressed

carcasses were further cut into parts to obtain the weights of fat pad, breast and thigh. Breast meat samples from each slaughtered bird were taken and stored for further analysis of dry matter and nitrogen.

3.6 Chemical analyses

3.6.1 Determination of dry matter (AOAC, 1990)

A clean crucible was placed in the oven set at 105 °C for 30 minutes. The crucible was then removed using metal tongs and allowed to cool for 20 minutes. It was then weighed to four decimal places [Wo]. Two grams of meat sample, feed refusals, feed or faeces were weighed into crucible [W_1], and crucible plus the sample were placed in the oven set at 105 °C for overnight. The crucible plus its contents were removed from the oven and allowed to cool to room temperature. After cooling, crucible plus dry sample [W_2] were then weighed. The dry matter content was then calculated using the formula:

DM (%) = $\{(W_2-W_0)\}/ \{(W_1-W_0)\}$ X 100

3.6.2. Determination of nitrogen and crude protein (AOAC, 1990)

Two grams of ground meat samples, feed refusals, faeces or feed were weighed on tarred ashless filter papers. The filter papers were then folded and placed in digestion tubes. Twenty-five milliliters of concentrated sulphuric acid and two tablets of a catalyst were added and tubes were then placed in the digestion unit. Water tubing was connected and tap water connected to the scrubber was turned on, and the power was also switched on. The tubes were gently heated at first and then the heating was increased after frothing ceased. The samples were digested until the solution was clear. The heat was turned off

and the digestion tubes were put in fumehood until cooled. The tubes were placed in a distillation unit for further distillation. Two drops of the indicator were added in an Erlenmeyer flask for each sample and the flasks were placed under the spout to receive ammonia. Titration of ammonia borate with hydrochloric acid was used to estimate the amount of nitrogen as follows:

N (% of sample) = (Volume of acid used in sample titration – Volume of acid used in blank titration) x (acid molarity x 0.014 x 100) / (weight of sample in gram x 1000).

Crude protein (%) = N % 6.25.

Therefore, Crude protein (on % DM basis) = (CP % / DM %) x 100

3.6.3 Determination of gross energy (AOAC, 1990)

The gross energies (GE) of the diet and excreta samples were determined using an adiabatic bomb calorimeter (Gallenkamp, University of Pretoria, South Africa). The apparent metabolisable energy (AME) content of the diets was calculated as follows:

AME = Energy in feed consumed – energy excreted in the faeces.

3.7 Tannin analyses

3.7.1 Extraction of polyphenols (FAO/IAEA, 2000)

A finely ground sample of 0.200 g dried plant material was weighed in a glass beaker of approximately 25 ml capacity. Ten milliliters of aqueous acetone 70 % or 50 % methanol was added, and the beaker was suspended in an ultrasonic water bath for 20 minutes at room temperature (25 °C). Contents of the beaker were centrifuged for 10 minutes at

approximately 3000 g using an ordinary clinic centrifuge. The supernatant was transferred to large test tubes and the solid was left in the small centrifuge tube.

3.7.2 Determination of total phenolics and tannin using Folin- Cioccalteu method (Makkar *et al*, 1993)

Suitable aliquots of the tannin-containing extract of 0.02 ml was pipetted into the test tubes. The volumes of 0.48 ml distilled water, 0.25 ml of the Folin-Cicalteu reagent and 1.25 ml of sodium carbonate solution were added. The tubes were vortexed and then allowed to stand for 40 minutes at room temperature. The absorbance at 725 nm was recorded. The amount of total phenolics was calculated as tannic acid equivalent using calibration curve. Total phenolics were expressed on a dry matter basis (% DM tannic acid equivalent).

3.7.3 Determination of simple phenolics using polyvinylpolypyrrolidone (PVPP) (Makkar *et al*, 1993)

A hundred milligram of PVPP was weighed into a 100 x 12 mm test tube, 1.0 ml distilled water and 1.0 ml of the tannin-containing extract was added. A hundred milligram of PVPP is sufficient to bind 2 mg of total phenols. If total phenolic content of the feed was more than 10 % on a dry matter basis, the extract was diluted appropriately. The tubes were vortexed and kept at 4 °C for 15 minutes. They were vortexed again before they were centrifuged at 300 g for 10 minutes and the supernatant was collected. This supernant had only simple phenolics other than tannins. The tannins had been precipitated along with the PVPP. The phenolic content of the supernant was measured

by taking three times the volume used for total phenol estimation, because the extract was already diluted two-fold and was expected to lose tannin-phenols through binding with PVPP. The absorbance was recorded at 725 nm after 40 minutes. The content of non-tannin phenols was expressed on a dry matter basis (% DM tannic acid equivalent).

3.7.4 Determination of condensed tannins (Waterman & Mole, 1994)

3.7.4.1 Extracted condensed tannins

A sample of 0.2 ml tannin extract diluted with 0.3 ml of acetone was pipetted into a 100 x 12 mm test tube. And 3.0 ml of butanl –HCL reagent and 0.1 ml of ferric acid were added. The tube was vortexed and then the mouth of the tube was covered with a glass marble and put in the heating block at 97 to 100 °C for 60 minutes. The tube was then allowed to cool and absorbance was recorded at 550 nm. The formula for calculating percentage of condensed tannins as leucoanthocyanidin equivalent is (absorbance 550 nm x 78.26 x dilution factor) / (% DM).

3.7.4.2 Unextracted condensed tannins

A 0.01 g of the pellet from condensed tannins extract, 3.0 ml of butanol HCL reagent and 0.1 ml of ferric acid were added into a 100 x 12 mm glass test tube. The tube was vortexed with the mouth of the tube covered with a glass marble and put in the heating block adjusted at 97 to 100 °C for 60 minutes. The tube was cooled and absorbance was recorded at 550 nm. For the blank, 0.5 ml of the extract, 3 ml of butanol and 0.1 of ferric

reagents were added. The formula for calculating percentage of condensed tannins in a gram of sample was: (Absorbance 550 nm/ weight of sample used) x (1000 mg) / (% DM).

3.7.5 Radial diffusion assay (Hagerman, 1987)

3.7.5.1 Preparation of plates

A 2.5 g agarose was weighed into 250 ml of the acetate buffer. The solution was heated to boil for 15 minutes with continuous stirring on a magnetic stirrer until agarose dissolved. The solution was allowed to cool to 45 °C by keeping the vessel containing the agarose solution into a water bath. A 250 mg BSA was added and dissolved in the agarose solution without allowing the solution to cool lower than 45 °C. A glass pipette of 10 ml with a large tip opening was used and approximately 10 ml of the solution was dispensed into each petri dish kept on a flat surface. The solution covered all the surfaces of the petri dish and allowed to be hardened. All the petri dishes were covered and sealed with strip of parafilm in order to prevent drying and cracking of the agarose layer. The petri dishes were stored for 4 days in a refrigerator.

3.7.5.2 Assay procedure

On the day of performing the assay, the petri dishes were taken out from the refrigerator, brought to room temperature and then opened. A puncher was used to punch four wells, far apart, in the solidified agarose in petri dishes. In each well 15, 30, 45 and 65 µl of the extract were pipetted. The petri dishes were covered and sealed again using parafilm. The

plates were placed in an oven adjusted at 30 °C . After 96 hours the petri dishes were removed from the oven, uncovered and the diameter of the ring was measured, if present, using a transparent millimeter ruler.

3.7.6 Protein binding capacity by filter paper assays (Dawra *et al.*, 1988)

The extraction was done using 70 % of acetone. A Whatman paper chromatography sheet of 1mm was cut into an appropriate size of 60 cm x 15 cm. The squares of approximately 3 cm^2 were drawn using a light lead pencil on the chromatography sheet. Different aliquot was done in triplicate (on three different squares). Amounts of 50 µl of plant extract were applied on the middle of the squares of the chromatography sheet. The spots were allowed to dry and immediately BSA was used to spray the paper until it was wet. The paper was washed with acetate buffer (pH 5; 0.05 M) with three 10 minutes changes with slight shaking to remove the unbound BSA. The paper was stained with 0.2 % Ponceau S dye solution by keeping the strips dipped for 10 minutes in the stain solution. The stain was washed in 0.2 % acetic acid solution until no more colour was eluted from the strips.

The strips were air dried and the stained areas were cut in small pieces and put in the test tubes where the colour was eluted by adding 3 ml of 0.1N sodium hydroxide solution and it was vortexed, followed by addition of 0.3 ml of 10 % acetic acid and centrifugation at approximately 2500 g. The absorbance of the colour was recorded at 525 nm against corresponding blank, which was done in the following way: a plain chromatography sheet was stained simultaneously as the sample chromatography and was washed in the

same manner to the samples. The absorbances were converted to protein content by using a standard curve. The standard curve was prepared by applying different concentrations of bovine serum albumin (BSA) (5 to 50 µl of 1 mg/ml BSA solution in the acetate buffer). This was applied as separate spots in triplicates for each concentration on a chromatography sheet and cut into strips. These strips were stained with the dye solution for 10 minutes, washed, dried and cut, and the absorbance was recorded the same way as for the samples. The calculations were done as tannic acid equivalent from the calibration curve and expressed as µg.

3.7.7 Reaction of polyethylene glycol (PEG) with tannins (Silanikove *et al*., 1994)

A stock solution containing 100 g/l PEG in a 0.5 m buffer Tris-BASE, pH 7.1 was prepared. A working solution was prepared by mixing 1 part of the stock solution and two parts of distilled water. The ratio between the plant sample weight and the working solution was 1:15. One gram of the sample was used. The reaction was carried out in 50 ml centrifuge tubes. After the samples had been mixed with the solution of distilled water (in the case of those untreated or control), the tubes were left for 24 hours in a horizontal position, with occasional mixing. The tubes were then centrifuged for 30 minutes at 2 500 g and the supernant was collected. Crucibles were dried in an oven to constant weights and then transferred into desiccators to cool down before weighing. A sample of 10 ml was poured into the crucible and then dried in the oven and then weighed after drying. The procedure of weighing and drying was repeated three times after every 30 minutes and weights were recorded for each period. This was done for treated and untreated feed samples.

3.8 Statistical analysis

Statistical analyses were conducted using the general linear model (GLM) procedure of the Statistical Analysis System (SAS, 1998) package. Analysis of variance was used to determine the effect of sex, dietary energy level and level of *Acacia karroo* leaf meal supplementation on diet intake, growth rate, feed conversion ratio, digestibility, nitrogen retention, and carcass characteristics. Duncan's Multiple Range Test was used to determine the significance of differences among the means (Duncan, 1955). Correlation analyses were used to relate tanniniferous feed supplementation level to animal performance indices (fat pad, digestibility and nitrogen retention).

CHAPTER 4
RESULTS

The high and low energy diets contained 11.05 and 11.98 ME DM, respectively, and 180 g crude protein per kilogram DM diet are shown in Table 4.1. Results of the nutrient composition of *Acacia karroo* leaf meal are presented in Table 4.2. *Acacia karroo* contained 120 g crude protein per kg DM, 1.5 % DM total phenolics, 4.5 % DM extracted condensed tannins and 3.72 % DM unextracted condensed tannins. The analysis by polyvinylpolypyrollidone, radial diffusion, polyethylene glycol and precipitable phenolics by filter paper showed that *A. karroo* leaf meal had 0.57 % DM, 4.00 mm^2, 039 mg/g and 0.24 µg, respectively.

The effects of dietary energy level and tanniniferous *A. karroo* leaf meal level of supplementation and their interactions on feed intake, growth rate and feed conversion ratio of male and female Ross 308 broiler chickens from 22 to 42 days of age are presented in Table 4.3. Dietary energy level, tanniniferous *A. karroo* leaf meal level of supplementation, sex and their interactions had no effect ($P > 0.05$) on growth rates and feed conversion ratio of broiler chickens. Within the same sex, dietary energy level and tanniniferous *A. karroo* leaf meal level of supplementation had no effect ($P > 0.05$) on feed intake of broiler chickens. However, when compared on the same diet, male broiler chickens had higher ($P < 0.05$) feed intake than female chickens.

Table 4.1 Nutrient composition of the grower diets (units are g/kg for dry matter, g/kg DM for protein, and ME/kg DM).

	Dietary treatments					
Nutrient	E_1To	E_1T_1	E_1T_2	E_2To	E_2T_1	T_2T_2
Dry Matter	917	919	916	918	918	919
ME	11.05	10.12	10.33	11.98	10.05	10.72
Protein	180	181	180	182	180	182

E_1To: Low energy diet without tanniniferous *Acacia karroo* leaf meal level supplementation.

E_1T_1 : Low energy diet with 9 g of tanniniferous *Acacia karroo* leaf meal level of supplementation/kg DM.

E_1T_2: Low energy diet with 12 g of tanniniferous *Acacia karroo* leaf meal level of supplementation/kg DM

E2To: High energy diet without tanniniferous *Acacia karroo* leaf meal level of supplementation

E_2T_1: High energy diet with 9 g of tanniniferous *Acacia karroo* leaf meal level of supplementation/kg DM

E_2T_1: High energy diet with 12 g of tanniniferous *Acacia karroo* leaf meal level of supplementation/kg DM

Table 4.2. Tannin analysis of *Acacia karroo* leaf meal by total phenolics (TP), polyvinylpolypyrrolidone (PVPP), radial diffusion (RD), extracted condensed tannins (ExCT), unextracted condensed tannins (UNExCT), polyethylene glycol (PEG) and precipitable phenolics by filter paper method (PPFP), dry matter and crude protein.

	Acacia karroo
Dry matter (g/kg)	90.7
Crude protein (g/kg DM)	120.0
Tannin contents by method of:	
TP (% DM)*	1.51
PVPP (% DM)	0.57
RD (mm^2)	4.00
ExCT (% DM) **	4.52
UnExCT (% DM) **	3.72
PEG (mg/g)	0.39
PPFP (µg)	0.24

* percentage DM tannic acid equivalent

** percentage DM Leucocyanidin equivalent

Table 4.3. Effect of dietary energy level and tanniniferous *Acacia karroo* leaf meal level of supplementation on feed intake (g DM/bird/ day), growth rate (g/ bird/ day) and feed conversion ratio (FCR) (g feed/g live weight gain) of male and female Ross 308 broiler chickens from 22 to 42 days of age.

Treatment	Feed intake	Growth rate	FCR
ME_1To	119.7^{ab}	57.1	2.0
ME_1T_1	117.6^{abc}	54.3	2.1
ME_1T_2	116.0^{abc}	46.2	2.5
ME_2To	122.8^{a}	51.9	2.3
ME_2T_1	120.7^{ab}	48.0	2.5
ME_2T_2	117.8^{abc}	43.9	2.5
FE_1To	111.8^{cde}	51.1	2.1
FE_1T_1	110.6^{de}	46.6	2.3
FE_1T_2	107.8^{e}	44.8	2.4
FE_2To	111.8^{cde}	42.6	2.5
FE_2T_1	113.2^{cde}	46.7	2.4
FE_2T_2	107.9^{e}	47.7	2.1
SE	2.194	2.957	0.119

$^{a, b, c, d, e}$: Means in the same column not sharing a common superscript are significantly different ($P<0.05$)

SE : Standard error

Results of the effect of dietary energy level and tanniniferous *Acacia karroo* leaf meal level of supplementation and their interactions on dry matter digestibility, crude protein digestibility, metabolisable energy and nitrogen retention of male and female broiler chickens between 38 and 42 days of age are presented in Table 4.4. Dietary energy level, tanniniferous *A. karroo* leaf meal level of supplementation and sex had no effect ($P > 0.05$) on dry matter and CP digestibilities, metabolisable energy and nitrogen retention in broiler chickens.

Dietary energy level, tanniniferous *A. karroo* leaf meal level of supplementation and sex had no effect ($P>0.05$) on carcass weight, dressing percentage, breast meat and thigh weights of broiler chickens (Table 4.5). Tanniniferous *A karroo* leaf meal supplementation had effects on fat pad weights. Broiler chickens supplemented with *A karroo* leaf meal had lower ($P<0.05$) fat pad weights than those not supplemented. However, sex of the chickens had no effect ($P>0.05$) on fat pad weights. Dietary energy level, *A. karroo* leaf meal level of supplementation and sex had no effect ($P > 0.05$) on crude protein content of breast meat samples of male and female broiler chickens (Table 4.6).

Table 4.4 Effect of dietary energy level and tanniniferous *Acacia karroo* leaf meal level of supplementation at finisher stage on dry matter digestibility, crude protein digestibility, metabolisable energy (ME) and nitrogen-retention of male and female Ross 308 broiler chickens between 38 and 42 days of age.

Treatment	DM digestibility	CP Digestibility (decimal)	ME (MJ/kg DM)	N-retention (g/bird/day)
ME_1To	0.58	0.88	10.88	3.20
ME_1T_1	0.51	0.87	9.88	3.00
ME_1T_2	0.49	0.87	10.15	3.03
ME_2To	0.58	0.88	11.55	3.20
ME_2T_1	0.47	0.87	9.46	2.80
ME_2T_2	0.50	0.87	10.05	2.73
FE_1To	0.60	0.90	11.22	3.20
FE_1T_1	0.53	0.88	10.37	3.10
FE_1T_2	0.56	0.87	10.51	2.80
FE_2To	0.61	0.90	12.40	3.20
FE_2T_1	0.55	0.87	10.64	3.10
FE_2T_2	0.54	0.87	11.39	3.10
SE	0.022	0.01	0.408	0.160

^{abcd} : Means in the same column not sharing a common superscript are significantly different ($P < 0.05$)

SE : Standard error

Table 4.5 Effect of dietary energy level and tanniniferous *A.karroo* leaf meal level of supplementation on carcass parts (g) and dressing percentage (%) of male and female Ross 308 broiler chickens at 42 days of age.

Treatment	Carcass weight	Dressing %	Fat pad	Breast	Thigh
ME_1To	1579	80	38^{a}	362	120
ME_1T_1	1642	77	28^{bc}	355	119
ME_1T_2	1704	79	27^{c}	366	126
ME_2To	1634	78	39^{a}	366	120
ME_2T_1	1549	79	29^{bc}	337	121
ME_2T_2	1495	75	28^{bc}	322	120
FE_1To	1474	79	38^{a}	352	117
FE_1T_1	1498	78	28^{bc}	366	116
FE_1T_2	1501	81	28^{bc}	333	113
FE_2To	1376	76	38^{a}	322	107
FE_2T_1	1454	77	28^{bc}	317	111
FE_2T_2	1236	66	28^{bc}	319	107
SE	85.978	4.095	2.747	19.5	5.028

$^{a, b, c}$: Means in the same column not sharing a common superscript are significantly different ($P < 0.05$)

SE : Standard error

Table 4.6. Effect of dietary energy level and tanniniferous *A.karroo* leaf meal level of supplementation on crude protein contents (% DM) of breast meat samples of male and female Ross 308 broiler chickens at 42 days of age.

Treatment	Crude Protein %
ME_1To	26.6
ME_1T_1	20.5
ME_1T_2	22.0
ME_2To	20.9
ME_2T_1	20.8
ME_2T_2	21.0
FE_1To	20.3
FE_1T_1	21.5
FE_1T_2	20.5
FE_2To	22.3
FE_2T_1	21.3
FE_2T_2	21.4
SE	0.516

SE: Standard error

A series of linear regressions that predict fat pad content, crude protein retention and dry matter digestibility in male and female Ross 308 broiler chickens from tanniniferous *Acacia karroo* leaf meal level of supplementation are presented in Table 4.7. *Acacia karroo* leaf meal level of supplementation was poorly correlated with fat pad of male (r^2 = 0.329) and female (r^2 = 0.071) broiler chickens fed a low energy diet. Moderate relationships (r^2 = 0.689) were observed between *Acacia karroo* leaf meal level of supplementation in broiler chickens fed a low energy diet. A similar trend was observed when the chickens were fed a high energy diet. Similarly, poor correlations were observed between *A. karroo* leaf meal level of supplementation and crude protein retention in broiler chickens.

Table 4.7 Prediction of diet dry matter digestibility (decimal), fat pad content (g/bird) and CP retention (g/bird/day) in male and female Ross 308 broiler chickens from tanniniferous *Acacia karroo* leaf meal level of supplementation.

Factor	Y-variable	Formulae	r^2	P
10.30 MJ/kg DM Feed				
A. karroo	male fat pad	y = -1.80x + 38.3	0.329	0.120
A. karroo	male CP retention	y = -0.24x + 22.5	0.024	0.237
A. karroo	DM digestibility (males)	y = 1.8x – 2	0.689	0.027
A. karroo	female fat pad	y = -7. 55x + 40.7	0.071	0.493
A. karroo	female CP retention	y = -0.61x + 23.3	0.332	0.003
A. karroo	DM digestibility (females)	y = 1.8x – 2	0.689	0.007
13.00 MJ/kg DM Feed				
A. karroo	male fat pad	y =-1.26x + 42.4	0.097	0.493
A. karroo	male CP retention	y = -0.32x + 20.5	0.062	0.062
A. karroo	DM digestibility (males)	y = 1.8x – 2	0.689	0.037
A. karroo	female fat pad	y = -1.40x + 47	0.456	0.018
A. karroo	female CP retention	y = -0.53x + 23	0.222	0.770
A. karroo	DM digestibility (females)	y = 1.8x – 2	0.689	0.044

r^2 : Correlation co-efficient

x : *A. karroo*

CHAPTER 5
DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

This experiment was designed to include high and low energy diets. The analyzed experimental grower diets had ME levels of 10.5 and 11.0 MJ/kg DM for Low and High diets, respectively. The *Acacia karroo* used in this study contained 120 g of crude protein per kg DM. This is quite high and ideal for supplementation in animal feeds (Makkar, 2003). Similar results have been reported elsewhere (Dube and Ndlovu, 1993, Kahiya *et al*., 2004; Mokoboki, 2005). However, *Acacia karroo* contained high concentrations of tannins, particularly condensed tannins. Dube and Ndlovu (1993) reported similar concentrations. Condensed tannins bind with diet protein and other nutrients, hence they tend to lower diet intake and digestibility in animals (Dube, 1993; Makkar, 2003). Thus, the performance of animals on high tanniniferous feeds is usually low (Makkar, 2003).

The present results showed that dietary energy levels had no effect on feed intake, growth rate, FCR, digestibility, nitrogen retention, carcass weight, fat pad, carcass parts and dressing percentage of broiler chickens. Metabolisable energy levels of the grower diets were not very different. Thus, lack of differences in intakes may have been expected. This is because broiler chickens eat primarily to satisfy their energy requirements (Scott *et al*., 1982), and hence feeds of similar energy levels will give similar intakes.

Acacia karroo leaf meal level of supplementation had no effect on growth rate, feed conversion ratio, carcass parts, dressing percentage and crude protein contents of breast meat of broiler chickens at 42 days of age. These results could be explained in terms of

similar intakes, digestibilities and nitrogen retention, irrespective of the treatment. Similar results were obtained by Al-Mamary *et al*. (2001) who found that addition of sorghum grains low in tannins to diets of rabbits did not change growth rate, feed intake and feed conversion ratio. Similar results were also reported by Diao *et al*. (1990). These findings are contrary to the findings of Laurena *et al*. (1984), Makkar (2003) and Hassan *et al*. (2003) who found adverse effects of tannins on feed efficiency, growth rate and protein digestibility.

Male broiler chickens ate more feeds than female chickens. These results are similar to those of Dozier *et al*. (2008) who found that male broiler chickens had higher feed intake than female chickens when both sexes were fed *ad libitum*. The differences were explained in terms of female chickens requiring on average 13 % less feed for maintenance per kg metabolic body weight than males. However, Gous *et al*. (1999) suggested that genetic potential influences broiler chicken growth responses because it affects their nutritional requirements. Thus, male broiler chickens have a pronounced genetic advantage of feed intake compared to female broiler chickens. However, there were no differences between sexes in growth rate, carcass weights, carcass parts and breast meat nitrogen content. These results may be explained in terms of similarities in digestibility values. These results are similar to the findings of Leeson and Summers. (1991) who found no differences between male and female growth rates and carcass weights. Similarly, Acar *et al*. (1993) reported that sex had similar effects on carcass weight and nitrogen content of breast meat of broiler chickens at 42 days of age. However, Lipens *et al*. (2000) reported that female broiler chickens yielded smaller carcass weights than male chickens. Han and Baker (1993), also, reported that sex had an

effect on carcass weight and nitrogen content of breast meat of broiler chickens. The differences were explained in terms of higher feed intake in male compared with female chickens. It was, additionally, suggested that the differences between sexes probably arise from metabolic differences and also from the differences in the onset of fattening of broiler chickens. *Acacia karroo* leaf meal supplementation had an effect on fat pad weights of broiler chickens. Supplementation with 9 and 12 g of *Acacia karroo* leaf meal per kg DM of feed reduced fat pad weights in male broiler chickens by 26 and 29 percentage points, respectively. Similarly, supplementation with 9 and 12 g of *Acacia karroo* leaf meal per kg DM feed reduced fat pad weights in female chickens by 26 percentage points. These reductions were achieved without any significant reduction in feed intake and or digestibility. The physiological explanation for this effect is not clear and it, thus, merits further investigation. However, it is known that *A. karroo* leaves contain high contents of condensed tannins which tend to bind with feed and endogenous proteins, and other nutrients, thus lowering diet intake and digestibility (Makkar, 2003). The presence of condensed tannins has been associated with reduced carcass fat in ruminant animals (Purchase and Keogh, 1984; Terril *et al*., 1992). However, no physiological explanations were given in their studies. No similar studies in chickens were found.

Low but positive correlations were found between *Acacia karroo* leaf meal level of supplementation and diet DM digestibility, fat pad weights and crude protein retention in broiler chickens. Mashimaite (2004) observed similar results in rabbits. No similar studies in chickens were found.

5.2 Conclusion and recommendations

Acacia karroo contained high amounts of condensed tannins. Supplementation with Acacia karroo leaf meal had no effect on diet intake, digestibility and live weight of broiler chickens. However, supplementation with 9 and 12 g of *Acacia karroo* leaf meal per kg DM feed reduced fat pad weights in male broiler chickens by 26 and 29 percentage points, respectively. Similarly, supplementation with 9 and 12 g of *Acacia karroo* leaf meal per kg DM feed reduced fat pad weights in female chickens by 26 percentage points. These reductions were achieved without any significant reduction in feed intake and digestibility. The physiological explanation for this effect is not clear and it, thus, merits further investigation.

CHAPTER 6

REFERENCES

6.0 References

ACAR, N., MORAN. E. T. & MULVANEY, D.R. 1993.. Breast muscle development of commercial broilers from hatching to twelve weeks of age. Poultry Science 73: 317-325.

AHN, D.U., SUNWOO, H. H., WOLFE, F. H., & SIM, S.J 1995. Effects of dietary alphalinolenic acid and starin of hen on the fatty acid composition, storage stability and flavor characteristics chicken egg. Poultry Science 74: 1540-1547.

ALLEDREGE, J., 1994. Effects of condensed tannins on browsers and grazers: Qualitative and Quantitative defense. Colorado State University, Fortcollins, Colorado, 805-823.

Al MAMARY, M., MOLHAM, A., ABDULWALI, A., & Al-OBEIDE, A. 2001. In vivo effect of dietary sorghum tannins on rabbits digestive enzyme and mineral absorption. Nutritional Research 21: 1393-1401.

ARMSTRONG, W. D., ROGLER, J. C., & FEATHERSON, W.R. 1974. Effect of tannin extraction on the performance of chicks fed bird resistant sorghum grain diets. Poultry Science 53: 714 -720.

AOAC, 1990. Official methods of Analysis; 15th Edition, Arlington.

BALOGUN, R. O., JONES, R. J., & HOLMES, J.H.G. 1998. Digestibility of some Tropical browse species varying in tannin content. Animal Feed Science and Technology 20: 203-218

BARRY, T. N. 1985. The role of condensed tannins in the nutritional value of *L. pedunculatus* for sheep. 3. Rates of body and wool growth. British Journal of Nutrition 54: 211- 217.

BARRY, T. N., & MANLEY, T.R 1986. Interrelationships between the concentrations of total condensed tannins, free condensed tannins and lignin in Lotus sp. and their possible consequences in ruminant nutrition. Journal of Science and Food in Agriculture 37: 248 - 254.

BARRY, T. N., MANLEY, T. R. & DUNCAN, S.J 1986. The role of condensed tannins in the nutritional value of *L. pedunculatus* for sheep. 4. Sites of carbohydrate and protein digestion as influenced by dietary reactive tannin concentration. British Journal of Nutrition 55:123-137.

BERNAYS, E. A., & BUTLER, L.G. 1989. Herbivores and plant tannins. Adv. Ecol. Res. 19: 263 –302. Abstract-GEOBASE.

BENTO, M. H., ACAMOVIC, T., & MAKKAR, H.P.S. 2005. The influence of tannin, pectin and polyethylene glycol on attachment of N-labelled rumen micro-organisms to cellulose, Animal Feed Science and Technology 136-160.

BOER, I. J. M., VAN DER TOGT, P. L., GROSSMAN, M., & R.P, KWAKKEL. 2001. Nutrient flows for poultry production. Poultry Science 79: 172 – 179.

BRAND, T. S., BADENHORST, H. A., KEMM, E. H., SIEBRITS, F. K., & HAYS, J.P. 1992. Studies on the chemical and digestible energy content of South African Grain sorghum. South African Journal of Animal Science 22: 43.

BRYANT, J. P., REICHARD, B. P., & CLAUSEN, T.P 1992. Chemically mediated interactions between woody plants and browsing mammals. Journal of Range

Management 45: 18 –24.

BUCHSBAUM, R., VALIELA, I. & SWAIN, T. 1984. The role of phenolics compounds and other plant constituents in feeding by Canada geese in a coastal marsh. Oecologia 63: 343 –349. Abstract- GEOBASE .

BUTLER, L. G. 1992. Anti nutritional effects of condensed and hydrolysable tannins. Basic Life Science 59: 693- 698.

CARPENTER, R., O'GRADY, M. N., O'CALLAGHAN, Y. C., O'BRIEN, N. M., & KERRY, J.P 2007. Evaluation of the antioxidant potential of grape seed and bearberry extracts in raw and cooked pork. Meat Science 76: 604-610.

CHERIAN, G. & WOLFE, F.W. 1996. Dietary oils with added tocopherols: Effect on eggs or tissue tocopherols, fatty acids and oxidative stability. Poultry Science 423-431.

DIAO, Q. Y., YANG Z. Y. & H.J, CHUN. 1990. The effects of sorghum tannin on digestion of nutrients in leghorn cocks. Chinese Animal Magazine 26 (2): 30- 32.

DOLLAHITE, J. W., PIGEON, R. F. & CAMP, B.J. 1962. The toxicity of gallic acid, pyrogallo, tannic acid and *quercus havardi* in the rabbit. American Journal of Veterinary Research 23: 126.

DOUGLAS, J. H., SULLIVAN, T. W., GONZALEZ, N. J. & BECK, M.M 1993. Differential age response of turkeys to protein and sorghum tannin levels. Poultry Science 72: 1944.

DOUGLAS, G.B., WANG, Y., WAGHORN, G. C., BARRY, T.N., PURCHAS, R.W., FOOTE, A. G. & WILSON, G.F.1995. Liveweight gain and wool production

of sheep grazing *L. corniculatus* and lucern (*Medicago sativa*). New Zealand Journal of Agriculture Research 38: 95-104.

DOZIER, W. A., DALE, N. M. & DOVE, C.R. 2003. Nutrient Composition of feed grade poultry by product meal. Journal of applied Poultry Research 12:526-530

DUBE, J.S., REED, J.D. & NDLOVU, L.R. 2001. Proanthocyanidins and other phenolics in Acacia leaves of Southern Africa. Animal Feed Science and Technology 91: 59 – 67.

DUNCAN, D.B. 1955. Multiple range test and multiple F tests, Biometrics II, 1-42

EVANS, M., ROBERTS, A. & A, REES. 2002. The future direction of cholesterol Lowering therapy. Curr. Opin. Lipodol 13: 663 –669.

FAO. 1999. Human nutrition in the developing world. Latham M.C. FAO Food and Nutrition Series No. 29.

FAO/ IAEA. 2000. Quantification of tannins in tree foliage IAEA-TECDOC, IAEA Vienna , Austria.

FISHER, R. & McNAB, J.M 1997. Techniques form determining the ME content of poultry feeds. In: Recent Advances in Animal Nutrition. Haresign and Cole Publication, Butterworth.

FLECK, D. C. & TOMBACK, F.D.1996. Tannin and protein in the diet of a food hoarding granivore, the western scrub-jay. Condor 98: 474- 482. Abstract-Elsevier BIOBASE.

FLORES, M. P., CASTANAN, J. I. & McNABB, J.M 1994. The effect of tannin on starch digestibility and TMEN of triticale and semi purified starches form triticale, and field beans. British Poultry Science 34: 281-286.

FOO, L.Y., MCNABB, W.C., WAGHORN, G.C. & ULYART, M.J 1996. Proanthocyanidi from *Lotus pendiculatus*. Photochemistry 45: 1689 –1696.

GOUS, R. M., MORAN, E. T., STILBORN, H. R., BRADFORD, G.D. & EMMANS G.C. 1999. Evaluation of the parameters needed to describe the overall growth, and the chemical growth and growth of feathers and breast muscles of broilers. Poultry Science 78:812-821.

HAGERMAN, A. E. 1987. Radial diffusion method for determining tannins in plant extracts. Journal of Chemical Ecology 13: 437 -449

HAGERMAN, A. E, RICE, M. E. & RITCHARD, T.N. 1998. Mechanisms of protein precipitation for two tannins, pentagallol glucose and epicatechin 16 (4 > 8) catechin. Journal of Agric. Food Chemistry 46: 2590 - 2595.

HAN, Y. & BAKER. D.H. 1993. Effects of sex, heat stress, body weight and genetic strain on the lysine requirement of broiler chicks. Poultry Science 72:701-708

HARBONE, J. 1998. Photochemical Methods: A Guide to Modern Techniques of Plant Analysis. Chapman & Hall, London.

HARGIS, S. P. & VAN ELSWYK, E.M.1993. Manipulating the fatty acids composition of poultry meat and eggs for health conscious consumer. World's Poultry Science Journal 49: 252.

HASSAN, I.A., ELZUBER, E.A. & TINAY, H.A 2003. Growth and apparent absorption of minerals in broiler chicks fed diets with low or high tannin contents. Tropical Animal Health Production 35: 189-196.

HELSPER, J. P., VAN LOON, Y. P., KWAKKEL, R. P. & VAN DER POEL, A.F.B. 1996. Growth of broiler chicks fed diets containing tanninfree and tannin

containing near-isogenic lines of faba beans. Journal of Agricultural Food Chemistry 44: 1070- 1-75.

HOLSHEIMER, P. J. & VEERKAMP, C.H 1992. Effect of dietary energy, protein and lysine content on performance and yiled of two strains of male broiler chicks. Poultry Science 71: 872-879.

HORIGOME, T., KUMAR, R. & OKAMOTO, K. 1988. The effects of condensed Tannins prepared from leaves of fodder plants on digestive enzymes in vitro and in the intestine of the rats. British Journal of Nutrition 60: 275- 285.

IDSO, S.B. & IDSO, K.E. 2002. Condensed tannins in ruminants and atmospheric CO2. A Novel Natural Way of Reducing Methane. Emissions 5: 32.

JANSMAN, A.J.M. 1993. Tannins in feedstuffs for simple stomached animals. Nutrition Research Review 6: 209-236.

JOHN, W. & LANCASHIRE, J.A. 1982. Proceedings of the New Zealand Grassland Association 42: 152-159.

JONES, J. T., ANDERSON, L. B. & ROSS, M.D. 1973. New Zealand Journal of Agricultural Research 16: 441- 446.

KAHIYA, C., MUKARATIWA, S. & THAMSBORG, S. M. 2004. Effects of *Acacia karroo* and *Acacia nilotica* diets on Haemonchus contortus infection in goats. Veterinary Physiology 115: 265-274.

KATAN, M. B. 2000. Nutritional interventions. The evidence. Proceedings Nutrition Society 59: 417 –418.

KARASOV, W. H., MEYER, M. W. & DARKEN, B.W 1992. Tannic acid inhibition of amino acids and sugar absorption by mouse and vole intestine: rests following

acute and subchronic exposure. Journal of Chemistry and Ecology 18: 719- 736.

KEMM, E.H. RAS, M. N. & DAIBER, K.H 1984. Nutrient digestibility and performance of pigs fed sorghum varying in polyphenol concentration and maize as grain sources. South African Journal of Animal Science 41: 1- 15.

KIM, H. S. & MILLER, D.D 2005. Proline rich in proteins moderate the inhibitory effect of tea on iron absorption in rats. Journal of Nutrition 135: 532 -537.

LAURENA, A. C., VAN DEN, T. & MENDOZA, M.E 1984. Effect of tannins on the in vitro digestibility of cowpea (*Vigna unguiculata*). Journal of Agricultural Food Chemistry 32: 1045- 1048.

LEESON, S. & J.D, SUMMERS. 1991. Commercial Poultry Nutrition. University Books, Quelph, Ontario Canada.

LEESON, S. 1995. New concepts in feeding broiler chickens. XIV Congress Latinoamericano de Agronomia. Chile 30- 40.

LEESON, S. 1996. Nutrition and broiler carcass quality. Hubbard Farms Technical Report.

LEESON, S., CASTON, L. & SUMMERS, J.D 1996. Broiler response to diet energy or energy and protein dilution in the finisher diet. Poultry Science 75: 522-528.

LEESON, S. 2004. Nutrition and Quality of the broiler carcass. http//www.omaf.gov.on.ca.

LEGE, K. E., SMITH, C. W. & COTHREN, J.T 1992. Genotypic and cultural effects on condensed tannins concentration of cotton leaves. Crop Science. 32: 1024 -1028.

LICHTENSTEIN, A. H. 1999. Nutrition Revision 57: 11 –14.

LIPENS, M., ROOM, G., DEGROOTE, G. & DECUYPERE, E. 2000. Early and temporary quantitave food restriction of broiler chickens-1 effects on performance

characteristics, mortality and meat quality. British Poultry Science 41:343-354.

LIZARDO, R., PEINIAU, J. & AUMAITRE, A. 1995. Effect of sorghum on performance, digestibility of dietary components and activities of pancreatic and intestinal enzymes in the weaned pig. Animal Feed Science and Technology 56: 67- 82.

LONGSTAFF, M.A. & MCNAB, J.M 1991a. The inhibitory effects of hull Polysaccharides and tannins of filed beans (*Vicia faba* L.) on the digestion of amino acids, starch and lipid and on digestive enzyme activities in young chicks. British Journal of Nutrition 65: 199-216.

LONGSTAFF, M.A., & McNAB, J.M 1991b. The effect of concentration of tannin-rich bean hulls (*Vicia faba* L.) on activities of lipase (EC 3.1.1.3) and alpha amylase (EC 3.2.1.1) in digesta and pancreas on the digestion of lipid and starch by young chicks. British Journal Nutrition 66: 139-147.

LONGSTAFF, M.A., McBAIN, B. & MCNAB, J.M 1991. The anti nutritive effect of proanthocyanidin-rich and proanthocyanidin-free hulls from field bean on digestion on nutrients and metabolisable energy in intact and caecectomised cockerels. Animal Feed Science Technology 34: 147- 161.

LUCBERT, J. & CASTAING, J. 1986. Utilization de sorghos differentes tenures and tannins pour Palimentation des poulets de chair. Proceedings 7th European Poultry conference 1: 472.

MAASDORP, B.V., MUCHENJE, V. & TITTERTON, M. 1999. Palatability and effect on dairy cow milk yield of dried fodder from the forage trees acacia coliviana, calliandra calothyrsus and leucaena leucocephala. Animal Feed

Science and Technology 77: 49-59.

MACLEOD, M.G. 1991. Fat deposition and heat production as response to surplus dietary energy in fowls given a wide range of metabolisable energy:protein. British Poultry Science 32: 1097-1108.

MAHMOUD, H. &MIHALY, S. 1998. Effects of L-carnitine supplementation of diets differing in energy levels on performance, abdominal fat content, yield and composition of edible meat broilers. British Journal of Nutrition 80: 391-400.

MAKKAR, H. P. S. 2003. Effects and fate of tannins in ruminant animals, adaptation to tannins and strategies to overcome detrimental effects of feeding tannin rich feeds. Small Ruminant Research 49: 241-256.

MAKKAR, H.P.S., BLUEMMEL, M., BOROWY, N.K. & BECKER, K. 1993. Gravimetric determination of tannins and their correlations with chemical and protein precipitation methods. Journal of Science, Food and Agriculture 61: 161-165.

MAKKAR, H.P.S., BLÜMMEL, M. & BECKER, K. 1995. Formation of complexes between polyvinyl pyrrolidones or polyethylene glycols and their implications in gas production and true digestibility in in-vitro techniques. British Journal of Nutrition 73: 897 –913.

MANSOORI, B. & ACAMOVIC, T. 1996. The effect of tannic acid on endogenous calcium, magnesium and phosphorus losses in broiler. British Poultry Science 37:67-71

MANSOORI, B & ACAMOVIC, T. 1998a. The influence of tannic acid on amino acid digestibility by broilers. In toxic Plants and Other Natural Toxicants, 101-105. CAB International.

MANSOORI, B & ACAMOVIC, T. 1998b. The excretion of minerals from broilers fed tannic acid, polyethylene glycol and protein. In toxic Plants and other Natural Toxicants, 106-110. CAB International.

MANSOORI, B & ACAMOVIC, T. 2000. The effect of polyethylene glycol and casein tannic acid complex on the loss of minerals in broilers. In: Proceeding of the XXI Worlds Poultry Congress, Montreal, Canada.

MANSOORI, B. & ACAMOVIC, T 2007. The effect of tannic acid on the excretion of endogenous methionine, histidine and lysine with broilers. Animal Feed Science and technology 134: 198-210.

MASHAMAITE, L.V. 2004. Relation between tannin contents using different tannin assays and short-term biological responses in rabbits supplemented with leaves of different Acacia species, M Sc Thesis, University of Limpopo, Department of Animal production, South Africa.

McKERSIE, B. D. & BROWN, D.C.W 1997. Biotechnology and the improvement of forage legumes. Biotechnology Agriculture, Series No 17, CAB International, Wallington, Axon, UK.

MEHANSHO, H., BUTTLER, L.G. & CARLSON, D.M 1987. Dietary tannins and Salivary prolinerich proteins: Interactions, inductions and defense mechanisms. Animal Review of Nutrition 7: 423-440.

MOKOBOKI, H.K., NDLOVU, L.R., NG'AMBI, J.W., MALATJIE, M.M &

NIKOLOVA, R.G. 2005. Nutritive value of Acacia tree foliages growing in the Limpopo province of South Africa. South African Journal of Animal Science 35:221-227.

MORAN, E. T. 1982. Comparative Nutrition of fowl and Swine. The Gastrointestinal Systems: 253 . University of Guelph, Guelph, Ontario.

MUHAMMED, S., STEWART C.S. & ACAMOVIC, T. 1994. The effect of tannic Acid on cellulose degradation, adhesion and enzymatic activity of rumen micro-organism. Proceedings of the Society of Nutritional Physiology 3: 174-176.

NRC. 1994. Nutrients requirements of Domestic Animals. Nutrient Requirements of Poultry. 9th edition, National Academy Press Washington.

ORITZ, L.T., AIZUETA, C., TERVINO, J. & CASTANO, M 1994. Effect of faba bean tannins on the growth and histological structure of the intestinal tract and liver of chicks and rats. British Poultry Science 35: 743-754.

PEDERSEN, C. V. 1998. Fare driven research on the village chicken production in Zimbabwe. http://www.iaea.org.

POUR-REZA, J. & EDRISS, M.A. 1997. Effects of dietary sorghum of different tannin concentration and tallow supplements on performance of broiler chicks. British Poultry Science 38: 512 -517.

PRIOLO, A., LANZA, M., PENNISI, P., BIONDI, L., & WAGHORN, G. 1998. Effect of condensed tannins in carob pulp on lamb meat quality. In Proceedings. VIII World Conference on Animal production, Seoul (Korea), June 1998: 908-909.

PRIOLO, A., & SALEM, B. 2002. Polyethylene glycol in concentration or feed blocks

to deactivate condensed tannins in *A. cyanophylla*. Effects on meat quality of barbarine lambs. Animal Science 75: 137-140.

PROVENZA, F.O., BURRIT, E.A., CLAUSEN, T.P., BRYANT, J. P. & RECHART, B.P. 1991. Conditioned Flavor aversion: a mechanism for goats to avoid condensed tannins in Blackbrush. American Nature 136: 810-828.

PURCHASE, R., & KEOGH, R 1984. Fatness of lambs on grassland Maku'lotus and grassland Huia' white clover. Proceedings of the New Zealand Society of Animal Production 44: 219-221.

REDDY, C. V. 2000. Maintaining growth and production. Poultry International 39 (2): 36-40.

REED, J.D., HOVARTH, P.J., ALLEN, M.S., & Van SOEST, P. J. 1985. Gravimetric determination of soluble phenolics including tannins from leaves by precipitation with trivalent ytterbium. Journal of Science Food and Agriculture 36: 255-261.

ROBBINS, C. T., HANLEY, T. A., HAGERMAN, A. E., HJELORD, O., BAKER, D. L., SCHWARTZ, C.C. & MAUTZ, W. W. 1987. Role of tannins in defending plants against ruminants reduction in protein availability. Ecology 68: 98.

ROSS, M. D., & JONES, W. T. 1974. New Zealand Journal of Agricultural Research 17: 191- 195.

SACKS, F. M. 2002. The role of high- density lipoprotein (HDL) cholesterol in the prevention and treatment of coronary heart disease. Am. J. Cardiol 15: 139 –143.

SAS Institute. Statistical analysis system. 1998. User's Guide. SAS Institute Inc. Cary, NC.

SHI, Z. C. 1988. Identification of the phenolics substances in bovine urine associated with oak leaf poisoning. Research Veterinary Science 45: 152.

SCOTT, M.L., NESHEIM, M.C., & YOUNG, R. J. 1982. Nutrition of the chicken . Third edition, M. L. Scott and Associates, publishers Ithaca, New York. pp 1-406.

SINGLETON, D.L. 1981. Naturally occurring food toxicants: phenolic substance of plant origin common in woods. Advanced in Food Research 27:149.

SILANIKOVE, N., NITEAU, Z., & PEREVOLOTY, A. 1994. Effect of polyethylene glycol supplementation on intake digestion of tannins containing in leaves (*ceratonia siliqua*) by sheep. Journal of Agriculture and Food Chemistry 42: 2844-2847.

SILANIKOVE, N., PEREVOLOTSKY, A., & PROVENZA, F. D. 2001. Use of tannin binding chemicals to assays for tannins and their negative postingestive effect in ruminants. Animal Feed Science and Technology 91: 69-81.

SONAIYA, E. B. 1999. Culture and Family Poultry Development IFE. Journal of the institute of cultural studies 7: 1 -10

SUMMERS, J.D., & LEESON, S. 1984. Influence of dietary protein and energy level on broiler performance and carcass composition. Nutrition Reports International 29: 757-767.

SUMMERS, J.D., SPRATT, D. & ATKINSON, J. N. 1992. Broiler weight gain and carcass composition when fed diets varying in a dietary energy and protein level. Poultry Science 71: 263-273.

TERRIL, T.H., WAGHORN, G.C., WOOLLEY, D.J., MCNABB, W.W. &

BARRY, T. N. 1994. Assay and digestion of 14^{c} labelled condensed tannins in gastrointestinal tract of sheep. British Journal of Nutrition 72: 467-477.

TERRIL, T.H., DOUGLAS, G.B., FOOTE, A.G., PURCHAS, R.W., WILSON, G.F. & BARRY, T. N. 1992. Effect of condensed tannins upon body growth, wool growth and rumen metabolism in sheep grazing Sulla (*Hedysarum coronarium*) and perennial pasture. Journal of Agriculture Science. Cambridge 119: 265-273.

Van DER POEL, A.F., DELLARET, L. M.W., VAN NOREL, A., & HELSPER J. P. F. 1992. The digestibility in piglets of faba bean as affected by breeding towards the absence of condensed tannins. British Journal of Nutrition 68: 793-800.

VISTA, V., PENNISI, P., LANZA, M., BARBAGALLO, D., BELLA, M. & PRIOLO, A. 2007. Intramuscular fatty acid composition of lambs given a tanniferous diet with or without polyethylene glycol supplementation. Meat Science 76: 739 – 745.

WAGHORN, G. C., REED, J. D. & L.R, NDLOVU L. R. 1999. Condensed tannins and herbivore nutrition. In Proceedings of the 18th International Grass Congress, 111.

WAGHORN, G. C., SHELTON, I. D., MCNABB, W. C. & McCUTCHEON, S. . 1994a. Effects of condensed tannins in *L. pendunculatus* on its nutritive value for sheep. 2 Nitrogenous aspects. Journal of Agricultural Science., Cambridge 123: 109-119.

WAGHORN, G.C., SHELTON, I.D. & MCNABB, W. C 1994. Effects of condensed tannins in *L. pendunculatus* on its nutritive value for sheep. 1 Nitrogenous aspect. Journal of Agricultural Science., Cambridge 123: 99-107.

WALDROUP, P.W., TIDWILL, N.M. & IZAT A.L. 1990. The effects of energy and

amino acids level on performance and carcass quality of male and female broilers grown separately. Poultry Science 69: 1513-1521.

WANG, Y., DOUGLAS, G.B., WAGHORN, G.C., BARRY, T. N. & FOOTE, A.G. 1996. Effect of condensed tannins in Lotus corniculatus upon lactation performance in ewes. Journal of Agricultural Science. Cambrigde 126: 353-362

WATERMAN, P.G. & MOLE, S. 1994. Analysis of phenolic plant metabolites. Blackwell Scientific Publications, Oxford. UK.

WOLFSON, M.M., DU TOIT, E.W. & CHESSEKER, P. 1993. Effect of plant leaf age on the production of tannins, phenols, proanthocyanidins and flavonols in Eulalia Villosa. Porceeding XVII International Grassland Congress: 595-597.

YOLSIN, S., OZOKAN, S., ACIKGOZ, Z. & OZKAN, K. 1990. Influence of dietary energy on performance carcass parts yields and nutrients composition of broilers reared at natural optimum and summer temperatures. British Poultry Science 39: 633-638.

YOSHIDA, T., HATANO, T. & ITO, H. 2000. Chemistry and function of vegetable polyphenols with high molecular weights. Biofactors 13: 121-125.

ABSTRACT

The study was conducted to determine the effect of dietary energy level and tanniniferous *Acacia karroo* leaf meal level of supplementation at finisher stage on performance and carcass characteristics of male and female Ross 308 broiler chickens. Three hundred and sixty, 21-day old male and female broiler chickens were assigned to twelve treatments with three replications of ten birds in a 2 (sex) x 3 (dietary energy level) x 3 (tanniniferous *Acacia karroo* leaf meal level) factorial, complete randomized design. Supplementation with *Acacia karroo* leaf meal had no effect on diet intake, digestibility and live weight of broiler chickens. However, supplementation with 9 and 12 g of *Acacia karroo* leaf meal per kg DM feed reduced fat pad weights in male broiler chickens by 26 and 29 percentage points, respectively. Similarly, supplementation with 9 and 12 g of *Acacia karroo* leaf meal per kg DM feed reduced fat pad weights in female chickens by 26 percentage points. These reductions were achieved without any significant reduction in feed intake and digestibility. However, the physiological explanation for this effect is not clear and it, thus, merits further investigation.