THE EFFECT OF SUBSTITUTING SUNFLOWER SEED CAKE WITH *ACACIA TORTILIS* PODS AS A PROTEIN SUPPLEMENT ON THE PERFORMANCE OF SMALL EAST AFRICAN GOATS

BY

NTAKWENDELA LEONIDAS

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT FOR THE REQUIREMENTS OF THE DEGREE OF MASTER OF SCIENCE (TROPICAL ANIMAL PRODUCTION) OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2003

ABSTRACT

Two experiments (growth and digestibility) were conducted to investigate the effect of substituting sunflower seed cake (SSC) with *Acacia tortilis* pods (Atp) as a protein supplement on the performance of Small East African Goats. *Brachiaria* hay was given as a basal diet while Atp, SSC, hominy meal (HM) and mineral mixture were used as components of the supplementary rations. Four treatment rations based on ground Atp and SSC as protein supplements were formulated in such a way that ground Atp replaced 0, 33.3, 66.7 and 100 % of SSC in T_1, T_2, T_3, and T_4 respectively. In growth study, 24 female weaner goats with mean initial body weight of 9.71± 1.56 kgs were randomly allocated to the four treatment diets. Each weaner goat was given *ad libitum* hay and supplementary diet at a rate of 20g/kg body weight. Feed intake and growth performances were recorded for 90 days. In experiment 2, digestibility study to evaluate the effect of dietary treatments on nutrient digestibility and nitrogen utilization was conducted using 12 male goats. In growth and intake study, hay and total dry matter intake tended to increase with increasing levels of *Acacia tortilis* pods in the supplementary diet, goats offered supplementary diet T_4 showed the highest intake. The CP intake did not differ significantly ($P>0.05$). The intake of ME was significantly ($P<0.05$) different only between T_1 and T_4. Significant ($P<0.05$) difference was observed in growth rate between the animals in T_1 and those in T_3 and T_4. Similarly, the feed utilization efficiency for animals in T_1 was significantly ($P<0.05$) lower than that of the animals in T_3 and T_4. The treatment diets had no significant ($P>0.05$) effect on the apparent digestibility of DM, OM, CP and NDF. There was no significant ($P>0.05$) difference between treatments on nitrogen utilisation, however nitrogen retention was slightly

DECLARATION

I, NTAKWENDELA LEONIDAS, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has not been submitted for a degree award in any other University.

Signature.......................................

Date..........16/6/2003..........................

COPYRIGHT

ACKNOWLEDGEMENT

I am very grateful to my supervisors, Prof A.E. Pereka of the Department of Veterinary Physiology, Biochemistry, Pharmacology and Toxicology and Prof L.A. Mtenga of the Department of Animal Science and Production (DASP) for their endless assistance and fruitful comments, criticisms and encouragement, which enabled me to accomplish this work. I would also like to express my appreciation for their patience and dedication, without which this work would not have been possible.

My sincere gratitude is here expressed to all members of the Academic staff in the Department of Animal Science and Production, who made my course work possible and good suggestions and constructive criticism to my research work. Thanks are also due to the technical staff for their assistance in the laboratory work. Furthermore special thanks go to Philip V. Mnembuka for assisting me with data collection and day to day management and handling of the experimental animals. Without his kind co-operation this work would have been difficult to execute.

I further acknowledge my colleague students in the MSc course for their constructive criticism, company, hospitality and for giving me a warm and friendly atmosphere during my stay at SUA. My sincere thanks to my wife Jennifer for her consistent encouragement and moral support and for taking care of our beloved daughter Jacqueline, while I was away.

Lastly but not least, I sincerely thank the Danish International Development Agency (DANIDA) through the SUA-MU-RVAU-Enreca (Enhancement of Research

Capacity) Project for the financial support granted without which this study would not have been undertaken.

DEDICATION

This work is dedicated to my parents, my wife Jennifer and our daughter Jacqueline.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ADF	acid detergent fibre
ARC	Agriculture Research Council
AtP	*Acacia tortilis* pods
Bwt	body weight
CCPP	contagious caprine pleuropneumonia
CF	crude fibre
CP	crude protein
CPI	crude protein intake
CRD	complete randomised design
DASP	Department of Animal Science and Production
DM	dry matter
DMD	dry matter digestibility
DMI	dry matter intake
DOM	digestible organic matter
FAO	Food and Agriculture Organisation
HCN	hydrocyanic acid
HM	hominy meal
ILCA	International Livestock Centre for Africa
IVDMD	*in vitro* dry matter digestibility
IVOMD	*in vitro* organic matter digestibility
MAFS	Ministry of Agriculture and Food Security
ME	metabolisable energy
MFN	metabolic faecal nitrogen

MJ	mega-joule
ml	millilitre
mm	millimetre
MPTs	multipurpose trees
N	nitrogen
NDF	neutral detergent fibre
NH3-N	ammonia nitrogen
NPN	non protein nitrogen
NRC	national research council
ODL	optimum dietary level
OM	organic matter
OMI	organic matter intake
P/E	protein-energy ratio
SD	standard deviation
SEA	Small East African goats
SEM	standard error of the mean
SSC	sunflower seed cake
SSM	sunflower seed meal
SUA	Sokoine University of Agriculture
USSC	undecorticated sunflower seed cake

CHAPTER ONE

INTRODUCTION

In the arid, semi-arid and humid areas of the tropics, there is a wide distribution of different breeds of goats. In the African and Indian sub-continent, the presence of the large goat concentration, which is approximately 94 % of total world population, has been reported (Chate, 2001). This widespread distribution of goats is concomitant with their importance as suppliers of both meat and milk. Thus, in the East African region, the total flock of about 69 million goats contributes approximately 31.6 % and 6 % of Africa's and World's total meat respectively. The widespread distribution and the preference of goat keeping within the developing tropical regions are due to a number of attributes that make them more suitable than cattle under same environments in the tropics. Thus, Pastoralists and smallholder farmers often prefer to keep local goats due to their useful attributes, such as high prolificacy, short generation interval, adaptation to adverse climates, their ability to survive extended periods of drought better than most other livestock, their capability of using roughages not available to other stock and the advantages of a small but efficient producer of meat and milk (Gall, 1996).

The prevailing level of production from local goats is generally low which is primarily due to poor feeding practices and lack of intensification of the production systems (Devendra, 1991). Poor quality forages and roughages, such as mature grass, straw, stover and many other plant and agro-industrial byproducts may be improved by physical, chemical or biological treatment. However, procedures for improving nutritive value by chemical methods have not been adopted by farmers because of lack of information and the cost of inputs.

The major system of small ruminant production in Tanzania is the traditional system. In the traditional management system, small ruminants are usually kept extensively. In this case animals are left out to search their own food from the natural grasslands throughout the year (Mero and Uden, 1998). However, the natural pastures dominating in the tropics are characterized by seasonal variations in quantity and quality attributed by early maturity during wet season and a rapid fall in the nutritive value during the dry season (Crowder and Chheda, 1982). Consequently therefore, deficient in protein for the most period of the year such that the pastures are unable to meet the maintenance and production requirements for the animal. This has resulted in the fluctuations observed in the growth pattern, alternate body weight gains, body weight losses, disease susceptibility and reduced breeding performance (Crowder and Chheda, 1982; ILCA, 1987).

Conventionally, the use of protein source concentrates such as sunflower seed cake and cotton seed cake has been frequently advocated as a means of supplementing natural pastures in Tanzania for improving small ruminant productivity (Kitalyi, 1982). Das and Sendalo (1990) observed a profound effect on productivity when high quality feed supplements based mainly on natural pastures were provided to small ruminants. However, the high costs, incosistencies in availability and supply of commercial concentrates have been the constraint beyond economic reach by resource-poor farmers (Shayo, 1992) such that alternatives have to be sought.

A wide variety of multipurpose tropical trees grown at the farmers' field can be used as nitrogen sources in supplementary feeds (Topps, 1992, Ondiek *et al.*, 2000). The leaves of multipurpose tree leaves and pods are potential nitrogen supplements (Ondiek *et al.*, 1999). These tree forages not only provide a cheap source of nitrogen, energy and micronutrients but have also many other advantages like their wide-spread on–farm availability and easy accessibilty to farmers, their laxative influence on the alimentary system, low degradability of N in the rumen and provision of variety in the diety. The tree leaves can be harvested, sundried and used in compounded protein supplemnts. The replacement of conventional ingredients by tree leaves will make such supplements cheaper than the commercial concentrates (Ondiek *et al.*, 2000).

Utilization of tree legumes and pods as an alternative protein supplement on ruminant feeding is gaining popularity (Liu *et al.*, 2001). Shrubs and trees with high crude protein in ruminant rations have been reported as an economical and sustainable way of enhancing rumen microbial activity (Goodchild and McMeniman (1994). Shayo and Udén (1997) and Ondiek *et al.* (2000) observed an improvement of low quality basal diet with an inclusion of legumes, browses, shrubs, leaves and tree pods.

Supplementation of low quality diets with tree pods has resulted in better performance of small ruminants (Bitende and Ledin, 1994). Pods from legume trees such as *Acacia tortilis* and *Acacia albida* have been used as a source of nitrogen to supplement grazing/browsing livestock (Shayo and Udén 1997; Bwire and

Wiktorsson, 2002). In this respect, pods supplemented to low quality forages supply cheap source of nitrogen, improve intake and overall animal performance (Shayo, 1992). According to Bwire and Wiktorsson (2002) tree pods are potential protein supplement for milk production in the semi-arid tropics.

Acacia tortilis is a common species in the Semi-arid Tropical Zone of the Central Tanzania. The pods (fruit plus seeds) become abundantly available during the dry season. A single tree of *Acacia tortilis* may yield as much as 28 to 206 kg of pods yearly (Shayo, 1992). For this matter, *Acacia tortilis* pods are regarded as cheap source of nutrients for grazing goats and could offer better prospects of acceptance to farmers since it is readily available and sustainable during the dry season in the semi-arid areas (Shayo, 1992). The pods also have relatively high crude protein contents with a range of 12.3 to 17.8 % (Göhl, 1981). However, to date there is a paucity of information on the extent to which *Acacia tortilis* pods can be utilized by goats in the semi-arid regions of Tanzania. The present study therefore, was undertaken to evaluate the effect of substituting sunflower seed cake with *Acacia tortilis* pods as a protein supplement on the performance of Small East Goats with the following specific objectives:

i. to investigate the effect of substituting sunflower seed cake with *Acacia tortilis* pods in supplementary diets on dry matter intake and growth performance of stall-fed growing goats fed *Brachiaria* hay as a basal diet.

ii. to investigate the effect of substituting sunflower seed cake with *Acacia tortilis* pods as a protein supplement on feed *in vivo* digestibility and nitrogen retention by goats.

iii. to evaluate the economic benefits of substituting SSC with Atp in growing goats rations.

CHAPTER TWO

LITERATURE REVIEW

2.1 General overview on small ruminant production in Tanzania

The local breeds of small ruminants (sheep and goats) in Tanzania have been stable in terms of performance as a result of natural selection (Kyomo, 1978). Their wide distribution in the tropics is due to their ability to withstand harsh conditions in the semi-arid and arid areas where the problem of shortage of forages and water is further aggravated by frequent occurrence of drought (Kiwuwa, 1992). The low feed requirements of sheep and goats enable them to be kept even in the densely populated areas (Gall, 1996).

The trend in small ruminants' population has shown that there has been a gradual increase in goat numbers from 1994 to 2001 (MAFS, 2001). Sheep numbers have been increasing gradually from 1998 to 2002, with a slight decline between 1994 and 1999. The reason for this decline in the sheep population may be due to deterioration in rangeland conditions. According to the Ministry of Agriculture and Food Security (2001), the population number of goats and sheep in Tanzania was estimated to be 12.6 and 3.5 million, respectively by the year 2003.

Natural pastures are the most important feed resources for small ruminants. The major limitations of natural pastures in Tanzania, as in other places in the tropics, are the low nutrient content and seasonal fluctuations in quantity. This inturn may lead to weight gain and weight loss during wet and dry season respectively (Devendra and Mc Leroy 1982). Diseases are another important constraint which lead to poor ruminant performance, and the main goat diseases in Tanzania include helminthoses, pneumonia, kid scours, footrot and abscesses (Madubi, 1997).

The goat is well adapted to different kinds of habitat and can suitably be integrated in the predominantly mixed crop-livestock small holder farming systems of Tanzania (Das and Sendalo, 1991). The importance of goats for meat, milk production, cash income and as an insurance against disaster need not be overemphasized (Devendra, 1987). Goats have several production and social functions, i.e, they are used in ceremonial feasting and for payment of social dues, also they have a special and extremely important function as sacrificial animals in most of the rural areas of Tanzania (Das and Sendalo, 1991). Apart from poultry and wildlife, a large proportion of animal protein supply in rural families is obtained from small ruminants. This is due to their small size and high prolificacy compared to cattle. Meat from small ruminants is locally considered a delicacy, and hence it is relatively more expensive than other sources of protein (Das and Sendalo, 1991). It is easier to increase the population of goats than large ruminants such as cattle and buffaloes. This is because, the capital investments for the farm is relatively low, average land holdings are usually small, the reproductive turnover of goats is high and goats can be managed easily by family labour (Devendra and McLeroy, 1982).

2.2 Important adaptive features of indigenous goats

2.2.1 Adaptation to tropical environment

Indigenous breeds of goats have adapted to their ecological conditions mostly through natural selection. Fedele et al. (1993) have substantiated that goats possess the capability to adapt their intake changeably with season depending on the quantity and quality of herbage. Findings documented by Smith (1973) show that goats have the ability to balance dietary energy and protein caused by environmental variation and management to match to their nutritional requirements as closely as possible. Above these facts, goats select a wide spectrum of plants or plant parts compared to cattle and sheep (Zeeman *et al.,* 1983). This behavioural trait of goats to utilize forages selectively coupled with the browsing habit facilitates their competence to survive under harsh tropical circumstances. Additionally, this gifted nature of goats does not only provide them with a better balanced ration, but also prevents the animals' detoxification mechanism from being confronted with a large dose of one single toxin (Moss, 1991).

2.2.2 Tolerance to diseases

Goats are tolerant to most tick-borne diseases with exception of some other diseases like haemorrhagic septicaemia, and this is believed to be attributed to their ability to utilise different plant species (Reynolds, 1986). In comparison to sheep, goats are more sensitive to pneumonia, gastroenteritis, parasites and contagious eczema but more tolerant to trypanosomiasis (Mboera and Kitalyi, 1994).

2.3 Factors influencing performance of local goats

Compared to the distribution of non-ruminants, the distribution of small ruminant species is more strongly influenced by agro-climatic and ecological conditions. In defining agro-climate ecological zone, ILCA (1987) has drawn upon classifications, which divide sub-Saharan Africa into five principal agro-ecological zones, i.e, arid, semi-arid, sub-humid, humid and highlands. Among these major ecological zones there are important differences in climatic, nutritive and disease-parasite environments (James and Phylo, 1984). These differences are the result of variation in such factors as amount and distribution of precipitation, elevation, soil fertility, solar radiation, temperature and relative humidity. Such differentiation becomes increasingly complicated as man-made social and economic factors are imposed on afore-mentioned factors. For instance, deviations from optimum climatic and environmental conditions induce physiological stresses to the animal. Adaptation to these stresses is often made at the expense of their reproductive output, unless a good system of management like construction of sheds and shed pens is introduced to make environment more favourable to them (James and Phylo, 1984).

2.3.1 Climatic factors

Climatic stress has been shown to have an effect on animal performance, thus temperature above or below its comfort zone for instance, increases metabolic rate either to keep the animal warm (shivering) or to assist in heat dissipation (Hafez, 1968). The outcome of this has been pinpointed out by McDowell (1968) and Smith and Magembe (1986) which include, reduction in milk production and fertility, delayed physical and sexual maturity and consequently prolonged intervals between generation interval, birth weight and mature weight. High temperatures and inadequate rainfall subject animals not only to heat stress, but also to inadequate feeding and low nutrient intake to sustain high production. An important reason for the depressive effect of high ambient temperature is presumably a depression of feed intake. It is a constant observation that feed intake goes down when animals are exposed to high temperatures (Johnson, 1987) cited by Pereka (1991). Pereka, (1991) reported a difference in milk yield when two groups of dairy goats were exposed at different temperature. The author reported that goats at 30 ^{0}C produced 22 % less milk than the goats at 12 ^{0}C. Climate also has important influence on the nature of natural vegetation, type of farming practices and may account to low feed intake (Webster and Wilson, 1980; Devendra, 1986;).

In Tanzania and in the tropics in general, natural pastures are characterised by low herbage yields, seasonal fall in protein content and digestibility due to their rapid growth and maturity (Karue, 1974). The decline in feed value is more pronounced in the dry season which lasts about 6 – 7 months making majority of indigenous animals to thrive on low quality herbage (Devendra, 1986). The consequence of this is mainly reflected by the animals' failure to meet their maintenance needs, and consequently decline in productivity (Atta-Krah and Sumberg, 1988). This calls for the need of supplementing these animals with other sources of feeds if productivity is to be enhanced.

2.3.2 Diseases

Diseases reduce the productivity of livestock in all agro-ecological zones and production systems. The most important disease constraints to livestock productivity in sub-Saharan Africa today are the parasitic and viral diseases that are vector transmitted (Mboera and Kitalyi, 1992). However, their wide distribution and severity is strongly influenced by the environment. ILCA (1992) pointed out that gastrointestinal nematodes impose severe economic impact on goat production in pastoral systems due to mortalities, reduced production as a result of sub-clinical parasitism and direct costs associated with their control. Apart from other parasitic infections reported by Mboera and Kitalyi (1992) namely, fleas, coccidiosis and *Oestrus ovis* larvae, helminthiasis was the most common health problem in Tanzania. Helminthiasis hinders goat production through body emaciation, inefficient food conversion and utilization, reduced growth and fertility (Kasuku and Tibaijuka, 1987). Other diseases of economic importance to small ruminants production in Tanzania include trypanosomiasis, diarrhoea (enteritis), pneumonia and abscesses as reported by Ngatia *et al.* (1989).

2.3.3 Socio-economic factors

Inadequate extension and veterinary delivery systems, lack of infrastructure for transportation, marketing, processing and storage facilities for animal products are among of the socio-economic factors which hamper animal productivity in Africa (MALD, 1989). Communal ownership of land has become a serious concern which results into improper land management (ILCA, 1981).

2.3.4 Nutritional factors

Under high and balanced plane of nutrition, the genetic make up of the animal becomes the only limiting factor of growth (Abunie, 1992). The level of energy intake together with protein:energy ratio have been found to be of significant importance in the performance of growing goats (Mtenga and Madsen, 1992). There is therefore a need to consider these ratios in formulating diets for ruminants. Responses to protein supplementation may be limited by low dietary energy contents. Lambs on high-protein allowance to high-energy diet have been reported to have superior growth performance than those given high-protein diets only (Mtenga, 1992). This is mainly because increased protein intake on low energy allowance results in increased excretion of urinary nitrogen (Shoo, 1986; Muhikambele, 1990) and ultimately no significant improvement in nitrogen balance or growth.

2.4 Nutritive value of hominy feed

Hominy feed is a by-product of maize grain and consists of bran, germ and part of the endosperm. It has a similar value to maize grain, but it contains more fat because the germ is included and it has slightly more protein (Table 1). Hominy feed is often erroneously called maize bran, a name that should be reversed for the bran coating without the germ. With dry milking methods, hominy feed is an excellent feed for both monogastric and ruminant animals (FAO, 1998).

Table 1: Chemical composition of hominy feed (as % DM)

DM	CP	NDF	ADF	ASH	Source
88.72	12.10	21.96	-	2.91	Ayo, 2002
94.15	10.76	57.00	12.30	4.88	Kapembe, 2002
94.08	12.02	30.63	11.14	4.96	Murro, 2002
92.40	10.65	47.24	8.81	4.80	Temu, 2001
93.22	12.02	3.10	39.21	5.53	Kimbi, 1997
-	12.70	29.00	11.90	5.90	Goromela, 1996
90.40	11.60	34.00	11.80	4.60	Bwire and Wiktorston, 1996
92.00	10.30	-	-	3.70	Kitalyi, 1982

2.5 Nutritive value of sunflower seed cake

There is considerable variation in the physical and chemical characteristics of sunflower seed meal (SSM) produced in different geographical locations, particularly in its crude protein and fibre contents (Topps and Oliver, 1993). The nutritive value of the undecorticated sunflower cake (USFC) so produced depends on the oil extraction process, the variety of sunflower and the proportion of the hulls removed during processing (Mandibaya *et al.* 1999). Sunflower cake provides a source of least degradable crude protein by microbes in the rumen (Chenost and Kayouli, 1997) and hence available to the animal through digestion in the small intestine.

Table 2: Chemical composition of sunflower seed cake (as % DM)

DM	CP	NDF	ADF	CF	Ash	Source
94.80	23.99	-	-	17.10	5.0	Temu, 2001
-	27.80	40.10	17.40	-	6.6	Goromela, 1996
93.23	21.9	51.90	45.9	-	5.1	Bwire and Wiktorsson, 1996
90.00	29.70-	-	-	32.3	5.0	McDonald *et al.* 1997
94.70	25.80	62.30	41.90	-	6.6	Shayo, 1992
92.7	32.40	-	-	17.10	5.0	Kitalyi, 1982

Oil seed cakes are incorporated into diets as protein supplements and because of their high protein content they are used to upgrade low quality roughage of a maintenance diet (Beddingar and Degefa, 1990). Processing affects the nutritional value in that the cake has a higher ash content, lower crude fat and higher crude protein than whole seed (Thomke and Macha, 1986). Sunflower meal contains phenolic compounds, chlorogenic acid, which has adverse effects on palatability and may reduce protein digestibility. With lysine supplementation, the decorticated sunflower meal can replace up to 50 % of the soybean meal in broiler and layer diets (Singh *et al.*, 1981). Up to two thirds of soybean meal may be substituted with good quality sunflower meal with supplemented lysine in grower and finisher feed. However, feed efficiency will be reduced significantly by using particularly dehulled sunflower meals due to the high fibre and lower energy content (Mandibaya *et al.*, 1999).

2.6 Feed intake

Feed intake is usually expressed as the amount of dry matter intake that an animal can consume per day (Charray *et al.*, 1992). The more the animal consumes each day, the greater the opportunity for increasing its daily production potential. Animals will choose a more digestible diet by generally rejecting stem portions if allowed a large amount of refusals. This ability is favoured by feeding the material in a long form and is reduced by chopping (Zemmelink, 1990).

Animals consume forage in varying amounts. Assessment of forage quality depends not only on the chemical composition and digestibility values of the forage but also on the quality of that forage voluntarily eaten (Crowder and Chheda, 1982). However, animals' intake of tropical forages, particularly of tropical grasses is considerably lower than temperate species (McDonald *et al.*, 1997). The low level of intake is considered to be the major cause of poor animal productivity in tropical environments. Ademosun (1974) studied the intake of several tropical grasses by goats in Nigeria and obtained dry matter intake values ranging from 25 to 48 g/kgW$^{0.75}$. These values are only one third of the figure recorded for temperate forages of the same species (Thorton and Minson, 1973). These low intake figures indicate serious limitations on forage utilisation in the tropics. Intake of tropical legumes, however, is considerably higher than that of tropical grasses (Crowder and Chheda, 1982).

Feed quality and physical characteristics of forage, such as dry matter content, fibre content, particle size, and resistance to fracture are known to affect ease of prehension and thus intake rate (Inoue *et al.,* 1994). Forages with low digestibility result in a slower rate of passage, thus restricting feed intake (McDonald et al., 1997). When adding concentrate to a low quality feed the intake of poor-quality foods is generally increased because the supplements stimulate the function of micro-organism in the rumen, thereby reduce the retention time (Bonsi and Osuji, 1997).

2.6.1 Voluntary feed intake

Voluntary food intake can be defined as the amount of feed an animal will ingest when an excess of 15% is offered (McDonald et al., 1997). The amount of feed which ruminants voluntarily consume greatly influences the efficiency with which they convert feed nutrients into valuable products like meat and milk (McDonald *et al.,* 1997). The capacity of feed intake in ruminants particularly goats, is variable. Daily dry matter intake for the East African goats fed to appetite as reported by Devendra and Burns (1983) ranges from 1.8 to 4.7 percent of their body weight. This big variation is attributed to inherent differences in breed, sex, age, physiological status and level of production. According to Devendra and Burns (1983) cited by

Devendra (1990), meat goats have intakes of 1.8 to 3.8 percent while dairy goats have 2.8 to 4.9 percent of body weight in the tropics and subtropics.

2.6.2 Factors affecting voluntary feed intake

Voluntary intake is primarily affected by three factors namely plant, climatic and the animal itself.

2.6.2.1 Plant factors

The plant cell wall contains the entire structural substance of the plant and Van Soest (1994) suggested that the only consistent factor limiting intake that can be observed in forages is the total cell wall (NDF) content. The cell contents, which can be measured as neutral detergent solubles, include soluble proteins, non-protein nitrogen compounds, sugars, starches, lipids and minerals. The digestibility of cell contents is high, being reported as 98 % (Van Soest, 1992). The main components of cell wall are cellulose, hemicellulose, lignin and residual ash (Van Soest, 1982). Lignin is known to be bonded strongly to hemicellulose and the nature of this bonding has been regarded as a barrier to digestion (McDonald *et al.,* 1997). The phenolic acids associated with lignin are active inhibitors of microbial enzymes. D' Mello (1992) demonstrated that the presence of tannins in the browse leaves lowered intake and digestibility. The total cell wall content in legumes which does not normally appear to become limiting lies between 50 and 60% of the forage dry matter. Fibre can account for rumen fill, and is highly correlated with both rumination and chewing time among a wide range of forages (Van Soest, 1988,) Roughages are sometimes chopped to reduce wastage and not alter the cell wall structure in such feeds (McDonald *et al.*, 1997). Devendra (1983) found no differences between long and chopped straw in dry matter intake (51 Vs 50 g/kg $W^{0.75}$ and digestibility (46 vs 41 %) by sheep. Physical state at which the feed is offered to the animal may have an influence on voluntary feed intake. Physical processing such as grinding or pelleting has been reported to increase its voluntary feed intake (Schneider and Flatt, 1975). The processed forage passes through the rumen at a faster rate hence permitting more forage to be consumed (Laredo and Minson, 1975a). When feed is chopped into short pieces, the length of the long fibres is decreased and the animals have less opportunity to select between the different fibre parts of the feed (Zemmelink, 1990). This leads to increased feed intake and reduced time of eating. However, when grass or hay is offered in long, unchopped form the animals have more opportunity to select between stem and leaf, which leads to increased nutritive value of the feed consumed and increased time for eating (Minson, 1971). According to ARC (1980) small ruminants are much more sensitive to particle size than cattle.

Forage intake tends to increase with forage quality (Piasentier *et al.*, 1995). Typical low quality roughages are characterised by low nutrient density, slow rates of breakdown and disappearance from reticulo-rumen and consequently low voluntary intake (McDonald *et al.*, 1997; Van Soest, 1994). Forage palatability also affects voluntary intake (Baumont, 1996). Palatability of a feed can be assessed by the preference for that feed measured in a choice situation. However, preference depends not only on the sensory properties of feed, but also on physical structure which influences the ease of prehension (Kenney and Black, 1984). With diets containing high proportion of roughages, intake is however limited by the capacity of the reticulo-rumen and the rate of disappearance of digesta from this organ (McDonald *et al.*, 1997). Other factors affecting intake rate include digestibility of plant species, their spatial distribution and seasonality of plant growth (Gordon, 1995). In studying voluntary intake of tropical grasses, Poppi *et al.* (1981b) demonstrated that retention time or disappearance rate of particles from the rumen was linked to particle breakdown.

The protein content of the diet has also been implicated in limiting the intake of tropical forages. Within the normal range of dietary protein concentrations voluntary intake is not affected by protein content. However, intake is depressed by diets of low or very high protein concentration (Forbes, 1995). Kamalzadeh *et al.* (1998) found that a higher nitrogen intake and a balance between nitrogen and energy resulted in higher grass hay intake and increased feed efficiency in lambs. Intake of grass species declines rapidly when the crude protein (CP) content of the consumed forage falls below 7% (Van Soest, 982). Below such levels the CP content is supposedly inadequate to supply sufficient NH_3-N for maximum fibre digestion in the rumen.

Feed allowance also affects intake and the tendency is for intake to increase with increasing herbage allowance (Piasentier *et al.*, 1995). The increase in intake with increasing allowance of feed is associated with the greater chances of the animal to select the most nutritious components of the forage.

2.6.2.2 Animal factors

The ingestive capacity of the animal depends on the species, sex, and physiological state of the animal such as age, pregnancy and lactation and environmental factors such as temperature and humidity (McDonald *et al.*, 1997). The physiological status affects the energy requirement of the animal and hence its intake. High feed intake is expected in actively growing or lactating animals since active removal of digested material takes place (Romney and Gill, 2000). This process causes either suppression of metabolic control of intake or a higher passage rate thus facilitating higher feed intake by an animal.

Stresses associated with heat and parasites have been found to depress feed consumption more in *Bos taurus* than in *Bos indicus* cattle (Firsch and Vercoe, 1978). Generally under *ad libitum* feeding conditions animals will stop eating when they have reached their physical capacity or when their energy requirements have been met (Kearl, 1982). The reduction of feed intake is more pronounced in diets with high roughage content (McDonald *et al.*, 1997).

Animal growth has a direct relationship with DMI of the food. Circumstances that change the size of the rumen and the size of the whole animal are likely to affect DMI. In ruminants, food intake follows the proportionality to the metabolic weight of the animal ($W^{0.75}$) (McDonald *et al.*, 1997). Body reserve in ruminant animals affects DMI. However, fatness may physically decrease the gut capacity by filling the abdominal cavity (Forbes, 1995). A thin cow eats more than a fat cow to compensate for the lost weight, however, this implies only when food with high energy is given (Faverdin *et al.*, 1995).

The nervous system is also involved in DMI regulation. In the brain especially in the hypothalamus there are areas which upon electrical stimulation cause the animal to stop eating while stimulation of another area accelerates eating. The signal to these centres can arise from physical stimulation of stretch receptors found in the wall of the stomach (Leek, 1986). Distension of the abomasum has also been shown to depress intake (Grovum and Phillips, 1978). The fermentation end products (mainly acetates, propionate and butyrate) plus other metabolites also have been implied to trigger the process of cessation of eating (Orskov and Ryle, 1990; Van Soest, 1994).

2.6.2.3 Climatic factors

Climatic factors play an important role in feed intake of farm animals. Dry matter intake (DMI) is negatively correlated with high ambient temperature and humidity. High ambient temperatures have been shown to depress voluntary feed intake by as much as 50% for sheep having access to feed for only part of the day (Bhattachrya and Hussain, 1974). A depression in voluntary feed intake was also observed in sheep kept under elevated temperature of 35°C than those kept under 18°C (Shafie *et al.*, 1994). High humidity, a factor that is often compounded with high ambient temperatures was associated with low feed consumption. Cattle maintained above 27°C were observed to consume less feed at 70% than at 40% of relative humidity.

In most cases, low intake of poor quality forages by ruminants in tropical countries may also be imposed by a combination of metabolic heat stress, high environmental temperatures and humidity (Leng *et al.,* 1992). Available evidence suggests that high levels of roughage in the diet under high temperature and humidity aggravate the heat dispersion mechanism in ruminants and reduce dry matter intake (Bhattachrya and Hussain, 1974). Under cold conditions, dry matter intake increases to enable the animal to ingest enough energy to maintain the body under thermostatic conditions (Shafie et al., 1994)

2.7 Growth performance in domestic animals

Growth is an increase in live weight and body size of an animal with time and is associated with actual biological synthesis of body tissues (Refsguard, 1978).

Growth rate can be conveniently grouped into two phases. Pre-weaning growth rate is the phase between birth and weaning where as post-weaning growth rate is the period between weaning and target weight. Pre-weaning growth rate coincides with accelerating phase of growth curve. During this phase the animal is growing at an increasing rate and nutrition especially the supply of milk from the dam becomes critical (Marsico *et al.,* 1993; Mourad, 1993). Post-weaning phase covers the period in the growth curve where animals are growing at a decreasing rate (Devendra and Burns, 1983). Sheep and goats in the tropics have generally lower growth rates compared to temperate breeds and their crosses when other factors are not limiting (Mourad, 1993). Without supplementation, growth rates of lambs have been reported to range from 31.3 to 95.9g/day and 95.5 to 99.5g/day in the pre-weaning and post-weaning phases respectively (Nyange, 1994) compared to values of 200 and

300g/day reported for lambs in temperate countries (Mtenga *et al.*, 1984; Mafwere, 1991). Values for tropical goats have been reported to be 44 and 24g/day for pre-weaning and post-weaning phases (Karua and Banda, 1990) compared to values of 150 and 250g/day for temperate goats (Madsen *et al.* 1990; Gebrelul *et al.*, 1994).

2.7.1 Factors influencing growth rate

Growth rate is defined as an increase in weight and body size associated with biosynthesis of body tissues. The rate of growth is one of the most important traits in meat production as it has implications in the amount of meat output obtained and age at target weights versus puberty and slaughter weight. Different growth rates have been reported in various parts of Africa. In Uganda, Ebong (1994) reported 27.1 to 103.3 g/day as growth rate of young, intact male goats. In Tanzania, Ayo (2002) reported daily gain of 19.7 – 25.1 g for post weaning growth rate. In Kenya, Gathuka (1986) reported growth rate of 110 and 90 g/day for Galla and Small East African Goats respectively.

It has been established that goats of different breeds, sex, plane of nutrition and management grow at different rates. Studying on the East African local goat breeds in Tanzania (Madubi, 1997) reported that, these animals have lower growth rate at any phase compared to imported temperate breeds when other factors are not limiting. However, under tropical conditions where there are harsh environmental conditions, lower growth rates are expected from the exotic breeds compared to local animals (Gebrelul *et al.*, 1994). There are many factors which influence growth rates in various growth phases in goats, and the key factors include breed, type of birth, nutrition, sex, management and diseases. These factors and their interactions between them are the main causes of variation between animal performances.

2.7.1.1 Breed

Generally indigenous goats in the tropics have lower growth rates at any phase in comparison to imported breeds and their crosses when other factors are not limiting (Peters and Deichert, 1984; Bradford and Berger, 1988). In Africa, Boer goats have excelled other local goats and other European goats in weaning weight (Abunie, 1992). Mohd *et al.* (1988) reported significant differences between various crossbred in pre-weaning growth rate in a study carried on Saanen x Katjag, Anglo Nubian x Katjag, British Alpine x Katjag and Katjag. In that study they found the highest weight gain in Saanen x Katjag (80.5 g/day) and the lowest weight gain was in Katjag (43.8). There is a positive correlation between weight and adult body size (Morand-Fehr, 1981). Malick *et al.* (1986) working on Beetal, Black Bengal and Black x beetal goats reported significant differences in birth weight between these breeds. This variation is expected since birth weight is correlated with mature body size and different breeds have different mature sizes (Abunie, 1992). An average daily gain ranging from 25 to 44g for various indigenous goat breeds have been observed (Shkolnik *et al.* 1980; Karua and Banda, 1990), while that of large breeds ranged from 54 – 80g (Madsen *et al.* 1990; Mourad, 1993; Gebrelul *et al.* 1994). Gebrelul *et al.* (1994) found that crosses of Alpine × Nubian grew faster than breeds from pure Alpine and Nubian (143 vs. 120 and 114g/day).

2.7.1.2 Sex

Many authors have reported male kids to be heavier than females at weaning. Ayoade and Butterworth (1992) found superior weight (16.3 kg) of males over females (15.4 kg). Kiango (1996) found significant effect of sex on weaning weight, males being heavier by 0.87 kg over females. However, Challya (1998) reported no significant difference in weaning weight between sexes. Also differences in pre-weaning growth rate between sexes have been reported in many studies (Kyomo, 1978, Bhattacharya, 1989, Berhanu et al. (1992). All these have showed that males grow faster than females. This could be attributed to differences which are genetically determined in muscle cell numbers, being greater in males than in females. Furthermore, the superiority of males over females is more pronounced when nutrition and other factors are not limiting during gestation period (Mtenga *et al.*, 1995).

Sex hormones are also important in determining differences between males and females in growth rates (Bradfield, 1968). Androgen hormones have been shown to have greater potency for growth than the female oestrogen hormones (Grossman, 1985). On average males are superior to females in birth weight by 5 to 20 % in sheep and 5 to 15 % in goats (Mchau, 1979; Morand-Fehr, 1981).

Other factors that influence growth rate differences between males and females are milk yield of the dam (Abunie, 1992) and management of animals in general (Kiango, 1996). When milk yield of the dam is low and hence consumption by kids is limiting, pre-weaning growth rate of females may be greater than that of males

(Mtenga, 1979). This is attributable to the greater demand for nutrients for male animals due to their heavier weights.

2.7.1.3 Type of birth

The type of birth has been reported to influence pre-weaning and post-weaning growth rates in sheep and goats; with singles being superior to multiples (Kyomo, 1978; Das and Sendalo, 1990). Das and Sendalo (1990) reported growth rate of 95.4 g/day for single born kids whereas it was 80.5 g/day for twins. They further found that these differences did not persist as the animal approached maturity. Infact, differences in growth rates between singles versus multiple kids is partly a reflection in differences in birth weight and differences in milk yield obtained from the dam. Although there is a tendency for does with twins to give more milk, milk available per kid is lower compared to does with single kids and hence the reduced growth rate. Furthermore, studies have shown that kids with low birth weights grow slower than those born with high birth weight (Madsen and Mtenga, 1988, Mtenga and Kiango, 1992). Lebbie and Manzin (1989) reported average growth rate of 68.2 g/day for the kid born lighter (i.e. 1.9 kg and less) compared to 94.3 g/day for kids born heavier (2.5 kg and above). In Tanzania, studies carried in Morogoro, West Kilimanjaro, Malya and Mpwapwa also indicated faster growth rates of single kids by 9.00 – 16.9 g/day than that of multiples (Das et al., 1989, Das and Sendalo, 1990).

2.7.1.4 Management and nutrition

Growth rates of goats have been reported under various nutritional and management levels in various parts of Africa. In Ethiopia, Mukasa Mugerwa *et al.* (1986) reported values of 124 and 59g/day as pre and post-weaning growth rates in sheep, while in goats the values were 104 and 65g/day respectively. In Uganda, Kiwuwa (1992) reported growth rates of 55 and 56g/kg for Mubende and SEA goats respectively. Management and nutrition of the young animals affects pre-weaning and post-weaning growth rates (Stanton, 1982, Rhindi, 1992). Hofs et al. (1984) studying growth and reproduction rates of West African Dwarf goats under high levels of feeding and management reported a pre-weaning growth rate of 83 g/day in indigenous goats. Moreover, rate of growth is generally increased as levels of protein and energy increases in the diet. In the study carried by Mc Gregor and Hodge (1988), faster (175 versus 118 g/day) growth rates of the kids fed oats and lucerne was observed when compared to kids fed oats and urea. In Nigeria, Ademosun *et al.* (1988), studying nutrtional effects on West African Dwarf goats in the humid tropics, reported growth rate up to 40 g/day of dwarf goats fed on standing hay supplemented with *Gliricidia sepium* and *Leucaena leucocephala*. In another study carried out at SUA, kids fed on *Bracharia* hay supplemented with brewers waste and *Leucaena leucocephala* were found to grow faster than kids on *Bracharia* and *Leucaena* or *Bracharia* alone (47.41 ± 0.45 versus 43.41 ± 0.19 and 28.78 ± 0.11 g/day), respectively (Kimambo *et al.*, 1989). Further studies at SUA on concentrate supplementation have demonstrated that growth rate can double or triple in goats if offered proper amount of protein and energy (Mafwere and Mtenga, 1992).

2.7.1.5 Diseases and parasites

Among the many constraints that limit productivity in livestock populations, diseases and parasites are of major importance. In Tanzania several reports have been written on livestock diseases, but with very little attention to small ruminant diseases. Nyange (1994) mentioned the incidences of diseases such as caprine pleuropneumonia and sheep pox in northern Tanzania, while Mbise et al (1984) reported incidences of anthrax and brucellosis. Matovelo *et al.* (1987) reported that parasitic gastroenteritis, pneumonia and diarrhoea were the dominant problems in the eastern part of the country. In central Tanzania, the majority of diseases reported by Mboera and Kitalyi (1992) were parasitic infections with helminthiasis and coccidiosis being the most prevalent. Constraints to animal production attributable to helmithiasis include inefficient food conversion, poor growth and reduced fertility. Furthermore, presence of parasites especially internal ones impairs intake and utilization of N resulting into poor growth rate. In parasite infestation low growth rate might probably be due to poor N metabolism which is again probably due to increased plasma protein loss into the digestive tract where some is excreted through faeces and urine (Kimambo, 1985).

2.8 Protein supplementation in ruminants

Proteins are essential building blocks for all living tissues and normally supply the raw materials that allow protein synthesis in the animal's body. This is of great importance particularly with growing stock (Webster and Wilson, 1980). Proteins are also components of enzymes and hormones, which constantly perform vital activities in metabolism and function of the animal. Feed intake, its digestibility and utilization in the animal body are often stimulated by protein or nitrogen supplementation (Martin *et al.*, 1981).

2.8.1 Effect of protein supplementation on feed intake

The protein content of the diet has been implicated as a limiting factor in the intake of tropical forages (McGregory, 1979). Intake of grass species declines rapidly when the CP content of the consumed forage falls below 7% (Van Soest, 1982). The authors noted that below such levels the CP content is supposedly inadequate to supply sufficient NH_3-N for maximum fibre digestion in the rumen. It is generally accepted that high protein supplements tend to stimulate high intake of fibres (Van Soest, 1982). Feed intake by ruminants can be increased by increasing the level of dietary protein through supplementation (Mtenga and Madsen, 1992). However, beyond a particular level of protein supplementation, the increase in feed intake is less spectacular (McGregory, 1979). There is therefore, an optimum level of dietary protein supplementation beyond which there is little or no response in feed intake with increasing levels of protein in the diet. Aganga *et al.* (1983) reported that the positive effects of dietary protein in improvement of voluntary intake or animal's performance depend on the form which the protein is supplied. Supplements based on natural protein sources are preferable to NPN supplements although the latter are faster in supplying N to the rumen microbes (Forbes, 1986).

Protein supplements increase the supply of N to the rumen micro-organisms which increases their population and efficiency (Schneider and Flatt, 1975). This in turn enhances the rate of breakdown of the digesta resulting into a higher passage rate and increased feed intake (Mc Donald *et al.*, 1997). Egan (1977) suggested that increased feed intake in animals fed low quality roughage has been a result of increasing the supply of amino acid to the tissues. Rumen micro-organisms are responsible for releasing the major part of the energy content of feed to meet the requirements of the host animal and for themselves by transforming dietary carbohydrates to acetate, propionate and butyrate (McDonald *et al.*, 1997).

2.8.2 Effect of protein supplementation on feed digestibility

Level of dietary protein influences DMI through its effect on dry matter digestibility (Devendra, 1986). The type of N supplementation could also influence the intake or digestibility response of low quality roughages by supplying different proportions of ammonia and peptides to the rumen micro-organisms and also variable amounts of amino acids to the host animal. Fadel *et al.* (1987) reported a small increase in NDF intake and digestibility in cows supplemented with fishmeal compared to that fed urea. When fed casein, cows tended to have higher NDF intake and lower NDF digestibility than urea-supplemented cows. They found that maximum intake and digestion in cows fed straw diets would be achieved when supplements contain degradable and undegradable sources of protein. Lyons *et al.* (1970) working with cattle, observed a significant increase in dry matter digestibility (DMD) as the CP content of the supplement increased from 10.3 to 33.3 % on DM basis at restricted roughage intake. However, some workers have reported that dietary level has no influence on DMD (McGregory, 1979; Mero and Uden, 1998). The same workers observed that at *ad libitum* roughage intake protein supplementation had no significant effect on DMD. This was explained by the fact that with poor quality roughages offered *ad libitum*, the high roughage concentrate ratios result into low energy intakes and eventually tend to lower the digestion coefficients.

Increasing dietary protein level has been associated with improved crude fibre (CF) digestibility (McGregory, 1979; Kitalyi, 1982). This may be due to the fact that protein supplementation increases the efficiency of cellulolytic bacteria through the supply of some branched chain fatty acids, which are necessary for the growth of the more active bacteria. Reynolds (1981) studied N metabolism in goats by varying N intake from 0.37g per kg $W^{0.75}$ to 1.86g per kg $W^{0.75}$ and observed that metabolic faecal N (MFN) accounted for about 46 and 18% of the total N excretion for the low and high N diets, respectively. Muhikambele et al. (1993) reported that, although the level of protein in the diet influences intake, digestibility and overall feed utilization efficiency in livestock, the effect of protein on performance depends on the balance of other nutrients particularly energy in the case of ruminants. In investigating the effect of protein supplementation on utilization of low quality roughage, it is important to meet the requirements of the animals for energy.

2.8.3 Effect of protein supplementation on growth rate

Protein deficiency in the diet depletes stores in the blood, liver and muscles and predisposes animals to a variety of serious and even fatal ailments (McDonald *et al.*, 1997). Protein level and source have been found to have an effect on feed intake and growth. Mtenga (1986) concluded (from various experiments with goats in Morogoro) that there is improvement in growth rate and feed conversion efficiency achieved by protein supplementation. Sighn *et al.* (1991) evaluated two rations containing 13.5% and 16.3% CP for their effect on feed intake, growth and digestibility of organic matter rations. The authors observed that feed intake and growth were higher in 16.3% than 13.5% protein diet. ARC (1990) reported that

DMD, intake and growth rate rose at an average of 0.01 units for each unit change in CP percentage for rations containing at least 16% crude protein. Higher levels of dietary protein are required for higher weight gains by sheep and goats. This statement is suported by Mafwere and Mtenga (1992) who observed that as dietary crude-protein level was increased from 11.36 to 13.22, 15 and 16.73%, corresponding growth rates of 34.14, 65.65, 68.01 and 70.5 g/day, respectively, were obtained for weaned lambs fattened on Chloris gayana hay and lablab meal as protein supplement.

2.8.4 Effect of protein supplementation on nitrogen utilization

Nitrogen enters the body only in the food, and leaves only in faeces and urine (McDonald *et al.*, 1997). The difference between dietary N and total N excreted in faeces and urine is termed as N balance or retention of a particular animal and may be positive, zero (at equilibrium) or negative depending on the level of N supply in diet and its efficiency utilization in the body. As nitrogen intake increases from a low level, there is a gradual reduction in the negative balance until the point of equilibrium is reached. The extent to which further increments of food-N promotes N-storage will depend on the age of the animal and the supply of other nutrients. Young animals store more N, while with balanced levels of other nutrients particularly energy, vitamins and minerals (probably plus water). However a stage is eventually reached, when further increment of protein intake fails to promote further N-retention (McDonald *et al.*, 1997). Muhikambele (1990) observed that, high levels of dietary protein intake lead to high level of urinary N excretion as urea. This is mainly due to the fact that, with high dietary N levels, the breakdown of protein usually exceeds microbial protein synthesis resulting in high levels of ammonia in the rumen, which is absorbed into the blood and carried to the liver and finally excreted in urine (McDonald *et al.*, 1997). Efficient dietary N utilization therefore, should be expected with low to moderate levels of protein supplementation than with higher protein levels (Kitalyi, 1982). Combined protein and energy supplementation will usually lead to higher N utilization efficiency (Sharma, 1979).

Studies with Leucaena in low-protein grass based diets in deer and sheep (Tomkins *et al.*, 1991), in growing goats (Mtenga and Shoo, 1990; Kimbi, 1997), rams (Muhikambele and Urio, 1988) and dairy cows (Muinga *et al.*, 1995) have all shown positive responses to supplementation. Also using other legume sources such as *Siratro* (Mero, 1985) or fruits of *Acacia sieberiana*, leaves of *Acacia seyal*, *Sesbania sesban* and *Vicia dasycarpa* hay (Reed *et al.*, 1990) have promoted positive N balances. Muhikambele and Urio (1988) compared kapok seed cake and Leucaena leaves as protein supplements to *Brachiaria* hay and maize bran-based diets and found that both protein sources increased N balance in Black Persian rams to a similar level. In the study by Reed et al. (1990), all legume supplements promoted positive nitrogen balances but the authors suggested that the N fractions in the diets containing *Acacias* had reduced N availability as a result of the influence of polyphenols in the *Acacia* on protein digestion.

2.9 Sources of protein for goats

Goats obtain dietary protein mainly from forages, but these do not always provide sufficient levels of protein for maintenance and growth. The sources of protein supplementation are usually important during the times of poor plant growth especially in the dry season. Legume seed meals, oil seed meals and cakes form a major source of protein, hence they are, often used in ruminants feed formulations (Neuman, 1977).

Ruminants have the ability to use non-protein nitrogen (NPN) to supply them with protein through microbial fermentation and growth in the rumen. Non-protein nitrogen sources such as urea can be used to improve feed utilization in ruminants (Martin *et al.*, 1981; Preston and Leng, 1987). The important factor for any source of protein to be of value, is that it must be consumed and digested, and the absorbed amino acids be utilized in the animal's body (Hutichson and Shelton, 1971). Protein sources differ in their degradability in the reticulo-rumen in supplying protein for microbes and in supplying bypass nitrogen. The extent of degradation largely depends on the solubility of the feed and the physical form of the diet as well as the retention time in the rumen and the level of intake (Aganga *et al.*, 1983). Unlike other domestic animals, goats have high preference for browse (Norton, 1984), hence feed on a variety of forage plants. Despite the little knowledge on the nutritive value of browse plants, the known types of trees and shrubs are nutritionally good, thus when goats get these browse herbage, in addition to legume and grass they get from grazing, they naturally acquire a lot of nutrients (Le Houerou, 1980).

2.10 Protein requirements for growing goats

Proteins are principal constituents of the animal body and are continuously needed for repair and in vital metabolic processes. In goats, as with other animals, protein requirements are dictated primarily by the physiological status than any other factor. The proteins consumed by goats are therefore utilised firstly for maintenance and if in adequate amounts, for production purposes (NRC, 1989).

The recommended protein requirements by NRC (1989) take cognisance of both maintenance and weight gain needs of goats. For maintenance the recommended level of protein, in total or crude protein (TP or CP) is 4.15 g/kg $W^{0.75}$ and for the growth a value of 0.284 g TP/g gain is indicate. Recent studies have also recommended protein requirements by goats separately for both maintenance and gain. Thus, Pralomkarm *et al.* (1995) using Thai and Anglo-Nubian goat crosses reported 4.4 ± 0.24 g digestible crude protein (DCP)/ kg $W^{0.75}$ for maintenance and 0.205 ± 0.033 g DCP/gain. However, due to genetic variations in rates of gain and sizes marked differences in protein requirements are to be expected markedly across breeds of goats (Morand-Fehr, 1989). Mtenga and Madsen (1992) have recommended that protein requirement should be related to energy level of the diet for better protein utilization. According to NRC (1989) protein requirement in relation to energy, that is crude protein/energy ratio (P/É)) for growing goats is about 9.4g CP per 1MJ ME, or 0.106MJ ME per 1g CPI.

2.11 The role of browse in livestock production

The shrubs and fodder trees have an important role in many agricultural farming systems. They can be used in multitude of ways including providing high quality forage to animals, contributing rich organic mulches to improve cropping land, stabilisation of degraded or saline land, providing firewood or poles for construction, or as living plant for shade or fence line (Dzowela *et al.*, 1997). Leaves and twigs of browse plants provide by far the bulk of the food to small ruminants in particular goats. Some species, however, are particularly important because of their fruits or seeds. Notable amongst these are *Acacia erioloba*, *A. albida* (large pods) and many other Acacia species, such as *A. nilotica*, which have very palatable, smaller pods. The smaller fruits of species such as *Ziziphus mucronata* and the *Grewia species* dry out and remain on the branches, providing a smaller but prolonged food source (Bray *et al.* 1984). Growth form can influence the degree of use beyond which the remaining browse is unobtainable, either through height or physical barrier (Le Houerou, 1978) such as *Acacia trees.*

The greatest value of foliages from multipurpose (MPTs) trees lies in their role as a diet supplement in the form of dietary nitrogen, energy, minerals and vitamins (Dzowela *et al.*, 1997). In Tanzania, they are particularly important in arid and semi-arid regions like those of central Tanzania where they are used to supplement low quality roughage in the dry season (Shayo 1998). Foliages from MPTs play a dual role in ruminant feeding as they help to provide and improve the ecosystem in the rumen, which is reflected in increased microbial activity, which in turn leads to an increased rate of digestion of the fibrous basal diet (Preston, 1987).

Browse plants are an important source of forage for both domesticated livestock and game throughout the tropics. Such plants are especially important during critical dry periods of the year when both the quantity and quality of pasture herbage is limited. Indeed it has been estimated that over 75% of the shrubs and trees of Africa serve as browse plants to some extent (Le Houerou, 1980a,b). In Australia, interest in fodder trees (with the exception of *Leucaena leucocephala*) has centred largely on native species, particularly the acacias (Bray *et al.*, 1984). Such trees have been regarded as sources of reserve feed for use in drought or prolonged dry season conditions.

Efforts to optimise the use of browse legumes to improve dry season feeding are more important now than ever due to increasing demand for animal products and high costs of conventional protein supplements. Shrubs and tree fodders are widely available and traditionally used by farmers, especially for ruminants. Tree legumes may help to increase livestock productivity in tropical regions by providing a high protein supplement. Tree legumes are locally adapted, require minimal input for establishment and maintenance and may be utilized in mixed farming systems (Atta-Krah and Sumberg, 1988).

Many fodder tree species have been evaluated in the tropics for use as feed resource for ruminant protein supplements. Some evaluated genera include *Albizia, Grewia, Delonix* (Goromela, 1996). Others, are *Sesbania, Leucaena, Acacia, Morus, Crotoralia, Gliricidia Cajanus,* and *Calliandra.*

2.11.1 Effects of supplementation with MPTs on DMI and growth rate

Supplementation of cereal crop residues with forage legumes has been shown to increase intake and digestibility (Mosi and Butterworth, 1985a,b), intake and digestibility (Minson and Milford, 1967). Minson and Milford (1967) reported that by including 10-20% forage legume in the diet, the voluntary intake of Pangola grass was increased, owing to the elimination of crude protein deficiency. Legume supplementation of grass diets with less than 7% crude protein (CP) has been shown to increase dry matter (DM) intake and animal performance (Wagner, 1989). The optimum dietary level (ODL) of protein supplementary forages was reported to be 30-50% or 0.9-1.5% of live weight (Devendra, 1988). Ash (1990) reported a significant increase in total DMI when *Gliricidia* and *Sesbania* leaves were used as supplement for guinea grass hay. However, Van Eys *et al.* (1986) did not find any effect on DM intake when Napier grass was supplemented with *Sesbania* or *Gliricidia*. Legume supplements have been proved to be more effective when fed with roughage containing less than 20 g N/kg digestible organic matter (DOM), as evidenced by higher rumen ammonia concentration from increased availability of ruminally fermentable N (Egan, 1986). Nherera *et al.* (1998) noted that high N content of most MPTs was positively correlated with OMI and DMD in ruminants consuming them. The authors suggested that tree fodder supplements alleviate N deficiency thereby improving the rate of degradation of the basal diet, passage rate and hence increasing feed intake. In Zimbabwe, Ndlovu and Sibanda (1996) reported growth rates as high as 67 g/day in goat kids offered 300-400 g/day of *Acacia tortilis* pods and concluded that, *A. tortilis* pods are suitable supplement for penned kids. However, Khalili and Varvikko (1992) observed a linear decline in total DMI and milk yield when a concentrate mix was substituted with wilted Sesbania forage. Girdhar *et al.* (1991) found that goats fed a grass-concentrate diet consumed more feed than goats fed a sole diet of *Leucaena*. In contrast, Yates and Panggabean (1988) found that at a given level of supplementation, total feed intake by goats was similar between grass-based diets supplemented with concentrate or *Leucaena*.

Variation in the feed intake response to tropical legume supplementation has been attributed to differences in form of feeding, plant parts fed or the variation in phenolic concentration across legumes (Reed *et al.*, 1990). Viengsavanh and Inger (2001) reported a higher daily weight gain to goats fed *Gliricidia* than those without, but only the diet with 30% *Gliricidia* was significantly different. Beyond this level, a slight decrease in daily live weight was observed.

2.11.2 Effects of supplementation with MPTs on dry matter digestibility

Supplementation of basal diets with MPTs increases essential nutrients available to rumen microbes and rate of passage. They affect protozoa population, milk yield and growth in cattle. Browse plants contain proteins, minerals and vitamins essential for the growth of microbes degrading feedstuffs in the rumen prior to subsequent gastric and intestinal digestion of the host. In the dry period, browses are richer than grasses in CP (Le Houerou, 1980) and their CF content tends to be lower than that of grasses and usually ranges between 20-40% (Pellew, 1980). DM digestibility in goats can vary widely according to diet (Ranjhan, 1980). However, Sharma (1979) indicated that the digestion in goats depends on the nature of the diet, level of feed intake, salivary secretion, pattern of rumen fermentation and movement of the alimentary tract. Barry and Reid (1984) reported that legumes have the tendency of binding feed proteins and rendering them unavailable to the rumen microbes. Many tree leaves, though similar to good quality fodder in chemical composition, have low palatability and nutrient digestibility because of the presence of deleterious factors, like tannins, essential oils or other aromatic compounds (Ravindra and Vaithiyanathan, 1989). Viengsavanh and Inger (2001) observed an increase in apparent DM, OM and CP digestibility when *Gliricidia* was offered at 30% level. They also noted that a higher level of *Gliricidia* beyond 30 % did not seem to affect the DM, OM and CP digestibility, although the CP intake increased significantly. Jones (1979) and Reed *et al.* (1990) reported that the supplement of fodder tree leaves should be about 30% of the diet, because of the secondary compounds which inhibit the digestibility and reduce the acceptability to animals at higher levels of inclusion. Stewart and Simons (1994) concluded that when used as a supplement, the optimum dietary level of fodder trees and shrubs should be about 30 to 50% of the ration on a DM basis.

A more practical way to improve the nutritive values of low-quality roughages in order to increase intake and digestibility can be achieved by adequate supplementation with browse leaves (Goodchild and McManimen, 1994). Most trees and shrubs have been documented to have high protein and mineral contents (Backlund and Bellskog, 1991) and to contain higher amount of digestible energy than grasses (Le Houerou, 1978). The form (fresh, wilted or dry) in which the leaves are fed to animals are said to affect both intake and digestibility in some browse species. Feeding of bulky and fibrous roughages tend to lower feed intake and digestibility because of the associated lignin content which have high negative correlation with the feed digestibility (Van Soest, 1982).

Studies by Bamualim *et al.* (1984) with goats and sheep given *Leucaena* as a supplement to spear grass showed an increase in total DM intake and an overall improvement in diet digestibility. In central Tanzania, sheep supplemented with low level *Acacia tortilis* and *Sesbania* leaves showed an increased intake and digestibility of DM and OM (Bitende and Ledin, 1994). The authors also noted that, at high level of supplementation intake was improved but not digestibility and resulted in depressed intake of the basal diet. Contrary to the above findigs, Preston (1987) demonstrated that supplements have beneficial effects on the utilisation of fibrous feeds if the level of supplementation does not exceed 20 % of the total diet DM to avoid the substitution of the digestible energy of the basal diet. Supplementation of rice straw with legumes at a level of 30% has been shown to significantly increase digestibility as well as total dry matter intake (McMeniman *et al.*, 1988). Legume supplements are usually most effective when fed with roughages containing less than 20 g N/kg digestible organic matter (DOM) because they increase the rumen ammonia concentration by providing ruminally fermentable N (Egan, 1986). Sarwatt (1989) reported an increase in DMD intake in sheep with increasing level of *Crotalaria ochroleuca* on grass hay as the basal diet.

2.11.3 Anti-nutritive factors in MPTs

Leaves of woody plants tend to contain more anti-nutritive components than those of herbaceous plants (Paterson *et al.*, 1998). According to Reed *et al.* (2000), there are over 24,000 structures in plants, including many compounds that have anti-nutrition and toxic effects on mammals. Rosales and Gill (1997) has reported the presence of more than 1200 different classes of chemical compounds that are produced by secondary metabolism. These compounds include; phenolic compounds, toxic amino acids, cyanogenic glycosides, saponins, alkaloids. Flavonoids including proanthocyanidins and estrogenic isoflavones, volatile terpernoids and components with strong odours (Makkar and Becker, 1998; Paterson *et al.*, 1998, Reed *et al.*, 2000, Shelton, 2001). Amongst these plants, there are about 8000 polyphenols, 270 non-protein amino acids, 32 cyanogens, 10,000 alkaloids and several saponins have been reported to occur (Rosales and Gill, 1997).

From nutritional point of view, the considerable interest in the presence of anti-quality compounds is warranted. Secondary and anti-nutritive compunds in plants have been implicated in causing mineral deficiencies, toxicity and illness or nutritional imbalances (Provenza and Ropp, 2001). Indeed some of the chemicals have been associated with reduction of forage digestibility, reduction of dry matter intake and overall forage quality and in some cases death of the animals (Allen and Segarra, 2001).

Leucaena is known for mimosine, a toxic amino acid that is high in concentration. The toxicity of this compound in ruminants is manifested as growth reduction or weight loss, excessive salivation, gut erosion and liver damage, general ill health and reproductive disorders (Paterson *et al.*, 1998, Nherera *et al.*, 1998). Tannins exist at varying levels either in the condensed or hydrolysable forms. Condensed tannins have been implcated in a number of browse plants. These compounds are highly polymerised proanthocyanidins composed of flavanoid units with molecular weight from 1000 – 20,000. Leng (1997) has indicated that tannin levels above 5 % of the diet dry matter can be serious anti-nutritive factors in ruminants. *Leucaena* foliage has been said to contain approximately 6 % of condensed tannins (Leng, 1997). The main effect associated with high tannin levels is increased DM intake due to reduced palatability or depressed ruminal digestion (Reed, 1995). This is because of the astrigency caused formation of complexes between salivary glycoproteins and tannins resulting in increased salivation and decreased palatability. In addition, high tannin levels have also been associated with reduced cell wall digestibility by binding bacterial enzyme and/ or forming indigestible complexes with cell wall carbohydrates. Consequently tannin effects results in overall reduction in true digestibility of true proteins, and for growing animals, this will be manifested as low growth rates (Reed, 1995).

Inspite of the problems posed by the secondary and anti-quality compounds, beneficial aspects of the same have been demonstrated in animals (Leng, 1997). At low levels, condensed tannins have been associated with improved nutritive value by protecting proteins and some essential amino acids against microbial degradation and hence making them by-pass protein the rumen to the small intestines (Jones *et al.*, 2000). From their study, Nguyen *et al.* (2002) demonstrated that low tannin levels (0.29 – 0.74 % DM) do not have any effect on nutritive value of diets. In addition, these compounds have been shown to confer beneficial animal health effects such as prevention of bloat and helminthiasis (Reed *et al.*, 2000).

2.12 *Acacia tortilis*

2.12.1 Description

Acacia tortilis is usually a medium-size tree (4 – 20 m tall), sometimes with several trunks that spray upwards and outwards that support a flat-topped umbrella of foliage. The foliage is feathery and typically acacia-like. The fragrant white or pale yellow flowers are borne in round clusters, and the ripe fruits-yellow-brown pods (8

– 10cm long) are spirally twisted, slightly constricted between the seeds, circular in cross-section, 0.6 to 0.8 cm thick. *Acacia tortilis* (Forsk) Haynne (subfamily Mimosoideae, family leguminosae) is one of about 135 African *acacias* species. Unlike the Australian *acacias*, African *acacias* are armed with thorns and produce highly palatable pods. *A. tortilis* is a variable species, with six intraspecific taxa including four recognised subspecies: *tortilis*, *spirocarpa*, *heteracantha*, and *raddiana* (Brenan 1983). As with other African *acacias*, *Acacia tortilis* is a polyploid complex most are tetrapods (2n =4x = 52); species radiana is an octoploid (2n =8x = 104). *Acacia tortilis* varies from multi-stemmed shrubs (*A. tortilis*), to trees up to 20 m tall with rounded crowns (*A. Radiana*) or flat-topped crowns (*A.Heteracantha* and *A.spirocarpa*). The presence of very long thorns and two thorn types, long straight and shorter hooked distinguish *Acacia tortilis* from other species in Africa. The alternate leaflets (usually less than 1 mm wide) are smaller than those of most bipinnate *acacias*. White or pale-yellow fragrant flowers cluster in 1 cm diameter round heads. Flowering is prolific with up to 400 flowers/meter twig. Flowers later develop into bunches of spirally twisted, indehiscent pods. Straight pods also occur, although rarely (Somalia and Kenya). Pods vary considerably in size depending on provenace but range from 8 to 12 cm long.

2.12.2 Distribution

Acacia tortilis often called the "umbrella thorn' for its distinctive spreading crown, is one of the most widespread trees in seasonally dry areas of Africa and the Middle East. The umbrella thorn is the dominant tree in many savannah communities and provides an important source of browse for both wild and domesticated animals. In

Africa, it occurs in the drier areas of Northern Africa, Senegal to Nigeria, in the Sudan, Kenya and Tanzania. In Kenya it occupies the desert grass-bush zones at altitudes of 1200m. In Malawi, this species is already scorned by the rural public because it is thorny and difficult to work with.

2.12.3 Ecology

Although it thrives where annual rainfall is 1000 mm, umbrella thorn is also extremely drought resistant and can survive in climates with less than 100mm annual rainfall and long, erratic dry seasons. The plant is too drought resistant, that specimens are sometimes found isolated in otherwise treeless arid environments. It does well too in hot climates with maximum temperatures as high as 50°C, and it grows where minimum temperatures are close to 0°C. The tree favours alkaline soils, but grows well in sand dunes, sandy loam, rocky soils and other soils that drain well. *Acacia tortilis* tree is reported to tolerate annual precipitation of 1 to 10 dm, estimated annual temperatures of 18 to 28°C, and pH of 6.5 to 8.5. Young *A. tortilis* forms natural thickets in heavily overgrazed savannah in southern Africa. It forms a deep taproot in sandy soil. On shallower soils and in sand sites, it can develop hosepipe subsurface roots extending over twice the width of the crown.

2.12.4 Cultivation

For good seed germination, seeds should be treated with concentrated sulphuric acid for 30 minutes (Roy *et al.*, 1973). Artificial generation aiming at large-scale nursery production requires full use of the germination capacity of the available seeds. This may be achieved by sulphuric acid pre-treatment, which brings about the germination of all viable seeds. Treatment with boiling water is selective and mainly breaks the dormancy of bruchid-infested seeds, some of which are no longer able to germinate. Sowing of unripe seeds without pre-treatment may be called for as an emergency measure in case of very severe infestation, to achieve at least partial success. Prior to storage, seeds should be fumigated to arrest processing deterioration of seed viability by bruchids. Roy *et al.* (1973) recommended dipping the seeds in hot water to soak overnight. Seedlings require initial weeding to facilitate faster growth. Lamprey (1967) found in Tarangere Game Reserve in Tanzania that seedlings of *Acacia tortilis* could only be found growing from faecal pellets of the Impala. He obtained no germination of seed from fallen pods, but 7% from seed collected from faecal pellets.

Goat enclosures at Maswa, Tanzania also have seedlings germinating from the dung, and Lamprey (1967) believed that such indehiscent pods must pass through an animal for regeneration to take place. Plantation by direct seeding of treated seeds should always be preferred in order to avoid the trauma of transporting and disturbing the tap root that grows about ten times faster than the stem. *Acacia tortilis* is a pioneer species easily regenerated from seed, pods are best collected by shaking them from the canopy. In East Africa, a mature tree can produce over 6000 pods in a good year, each with 8-16 seeds (10,000-50,000/kg depending on the subspecies). Shayo (1992) reported the total pod production which ranged from 28.1 to 206.2 (mean = 93.4 +- 44.2 SD) kg per tree. Furthermore, he reported that one hectare may produce around 9000 kg of pods a season. Seeds are often extracted by pounding pods in a mortar followed by winnowing and cleaning. The hard-coated seeds remain viable for several years under cool, dry conditions. Seeds are planted in the ground in 1cm deep holes or in the nursery in 30 cm long tubes. Rapid taproot growth requires frequent root pruning. Seedlings are ready to be planted out after 3-8 months. On marginal sites, initial seedling growth is often slow but quickens once roots have reached a water source. For best growth, plants should be weeded and protected from browsing animals for the first three years.

2.12.5 Biotic factors

Bruchids are small beetles, typically less than 1cm long, many of which are of great agricultural importance because they seriously damage the seeds of leguminous crop plants. They often damage or destroy the seeds of *Acacia tortilis* pods on the tree or after collecting. Herbivores, tame and wild alike, are liable to graze seedlings. *A. tortilis* trees are attacked by beetles, mimosoid blights, and caterpillars. The wood is susceptible to termites. In Tanzania, elephants, which eat the bark, are wiping out some park populations. In Israel, the native *Acacias* host several species (>40) of mostly monophagous insects. In nature, regeneration and spread of *Acacias* are probably limited by bruchids destroying much of the seed crop. Seedlings from natural regeneration may come from damaged seeds with a still intact embryo axis, since seed coat dormancy is removed by the effect of exit holes permitting rapid water absorption and germination. Intact seeds with hard impermeable seed coats may require a long time to germinate, and probably function as a reserve to ensure the survival of the species (Dougall and Bogdan, 1958).

2.12.6 Use and nutritive value of *Acacia tortilis*

Leaves and young trees are browsed by goats, but the main value of this species is in pods, which can be very numerous and are picked up from the ground and eaten by livestock (Dougall and Bogdan, 1958). The authors also reported that, at the time when pods are mature (usually in January – February in Kenya), they are often the main source of food for cattle, sheep and goats. It is the tree most recommended for reclaiming dunes in India and Africa (Roy *et al.,* 1973). The bark said to be a good source of tannin (Roy *et al.,* 1973). In other areas the trees are not cut, to avoid reducing pod yields. The plant copices well, so that there is no need to replant trees after every harvest for fuel wood. The species is excellent for soil stabilisation and it can fix nitrogen in the soil (Le Houerou, 1980), while the trunks and branches may be used for furniture making and construction. It produces gums of pharmaceutical interest (Sheik, 1982), and may also be used for tanning (Wickens, 1980). In silvi-pastoral systems, *Acacia tortilis* tree has a number of uses. Studies on the effect of 8-year old shelter belts with *Acacia tortilis* have indicated that trees may considerably reduce wind speed, wind erosion and evaporative moisture loss from the fields (Gupta *et al.,* 1983). *Acacia tortilis* may also play a role in crop and livestock production in the semi-arid areas where temperatures might be very high during the day, by providing shade to the livestock and a favourable micro-climate for the crops when grown with appropriate spacing (Shayo, 1992). Some of the most palatable grass species grow beneath its canopy (Walker 1979). In Turkana, Kenya, soil nutrients and herbaceous plant productivity and diversity were significantly higher under than away from the tree canopy (Weltzin and Coughenour 1990). In Kenya, fruits are eaten, the Turkana make porridge from pods after extracting the seed, and the Masai eat the immature seeds (Dougall and Bogdan, 1958). Pods are collected for sale in markets, such as in Lowar (Turkana) and Msinga (South Africa), both as animal and human food. Pods are also fed to lactating animals to increase milk yields (Bwire and Wiktorsson, 2002). *Acacia tortilis* seeds have been reported by Shayo (1992) to contain higher levels of nutrients important for milk production. Leaves, bark, and seeds are used in many local medicines. Two pharmacologically active compounds for treating asthma have been isolated from the bark (Hagos *et al.,* 1987).

The main importance of *Acacia tortilis* for livestock production lies in the value of the leaves of the young trees and pods as forage (Gwyne, 1969). Although the leaves contain considerable amounts of nutrients for maintenance and production, they are less available to cattle, as the plant possesses numerous spines/thorns that reduce access to the leaves (Göhl, 1981). The leaves may, however, be browsed by goats and sheep, and become more important towards the end of the dry season (Webb, 1988). The nutritive value of Acacia pods in relation to livestock productivity has been reported by various authors, but most of the results are limited to the chemical composition, and often only to the proximate values (Le houreou, 1980; Olsson and Welin-Berger, 1989). Leaves and pods have a good level of digestible protein (mean = 12 %) and energy 6.1 MJ /kgDM (Le houerou, 1980), as well as being rich in minerals. Seeds are high in crude protein (38 %) and phosphorus, an element usually scarce in grasslands (Göhl, 1981). Over 90 % of the tree's flowers abort and drop from the trees, providing an additional important forage (Webb, 1988). It appears that the nutritive value of *Acacia tortilis* pods varies with season (Coppock *et al.*, 1987) and region (Göhl, 1981). For instance, Göhl (1981) reported 17.8% CP of

Acacia tortilis pods from Kenya, while those from Tanzania had 12.3% CP. Dougall and Bogdan (1958) reported the CP of *Acacia tortilis* pods collected from the same site in January and February to be 17.8% and 10.4% respectively. The high digestibility and rumen degradability of *Acacia* pods confirm their appropriateness as a high quality supplement for improved cows (Shayo 1992).

Table 3: Chemical composition of different parts of *Acacia tortilis* pods

Part	DM	CP	NDF	ADF	Ash	Source
Whole pods	93.95	19.12	39.89	29.49	7.64	Ngwa *et al.* 2000
Whole pods	90.20	13.40	44.00	32.2	4.10	Shayo (1992)
Seeds only	92.2	18.6	42.8	25.3	3.7	Shayo (1992)
Seeds only	-	19.1	33.7	23.9	4.6	Tanner *et al.* (1990)
Seeds only	-	37.8	-	-	5.9	Gohl (1981)
Whole pods- S. Africa	-	17.30	-	-	5.70	Gohl (1981)
Whole pods-Tanzania	-	12.30	-	-	5.60	Gohl (1981)
Whole pods-Kenya	-	17.80	-	-	8.40	Gohl (1981)
Whole pods-Kenya	-	17.79	-	-	8.37	Gwyne (1969)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the experimental site

Growth and intake studies were conducted at Magadu Farm of the Department of Animal Science and Production, while a digestibility study was carried out at the University Farm premises. Both farms belong to the Sokoine University of Agriculture (SUA) Morogoro. The area experiences four types of seasons characterised by short rainy season (early October – January), short dry spell (February), long rainy season (early March – late May) and long dry period (June – September). The area receives about 600 – 1000 mm rainfall annually.The temperature ranges from 15 to 30oC with the hottest periods being October to January. Average monthly relative humidity is about 49% during the dry season and 66% during the wet season.

3.2 Source and preparation of experimental materials

3.2.1 Grass hay

Brachiaria brizantha grass hay was used as the basal diet for intake, growth and digestibility studies. This was purchased from Saint Gasper College located at Nanenane area in Morogoro municipality. The hay was harvested from a pure stand of *Bricharia brizantha* at the blooming stage early in the dry season. During the experimental period, the hay was chopped (about 7 – 10cm length) by using electric forage chopper so as to promote intake and minimize wastage.

3.2.2 *Acacia tortilis* pods

Acacia tortilis pods (plate 1 for *Acacia* tree and plate 2 for pods) were collected during the dry season of October/November 2001 at the Livestock Production Research Institute, Mpwapwa district in Central Tanzania. The Institute is located in the semi-arid agro-ecological zone at 36°32'E longitude and 6°21'S latitude and at an elevation of 1100 m above sea level. The area experiences a dry Savannah type of climate characterised by a long dry season between May and November and short wet season from December to April with an average annual raifall of 650 mm per year. The mean temperature ranges from 25 to 30oC.

The pods were coarsely ground in a local feed milling machine at Mpwapwa. Thereafter they were packed into dry sacks, and transported to Sokoine University of Agriculture, Morogoro.

3.2.3 Hominy meal

Hominy meal was purchased from local maize mills in Morogoro Municipality. It was sundried for three days so as to reduce its moisture content at least to 10% before storage and feeding.

3.2.4 Sunflower seed cake

Sunflower seed cake (SSC) was purchased from a local oil seed-pressing machine in Mpwapwa, Dodoma region. It was then ground in a feed mill.

3.2.5 Minerals, drugs and vitamins

Maclik super™ manufactured by Cooper Kenya Limited was purchased from KV Animal Health Centre, Morogoro. The Mineral composition as specified by manufactures is shown in Table 4.

Table 4: Mineral composition of Maclik Super (expressed as %)

Ca	P	Mg	Fe	Cu	Mn	Zn	S	Co	I	Se	Mo	NaCl	Na:P
18.51	11.0	3.0	0.5	0.16	0.4	0.5	0.4	0.02	0.02	0.0015	0.0002	27	1.68: 1

The injectable multivitamins (VITAJECT), and injectable dewormer (Levamisole) and Dominex™ acaricide were purchased from Kibo Agrovet shop in Morogoro Municipality.

3.2.6 Experimental animals

A total of 24 female weaner goats (of Dodoma strain) used in the growth and intake study were obtained from DASP/ENRECA goat herd (see plate 3). The goats were identified using metal ear tags. It was initially intended to use both female and male weaner goats for the growth and intake study, unfortunately males were not available in sufficient numbers at the onset of experiment. The animals selected for the experiment had average body weight of 9.71 ± 1.56 kg and the age ranged between 8 and 9 months old. Twelve (12) adult bucks used in digestibility study were also obtained from the DASP/ ENRECA Project goat herd.

3.3 Formulation of the test diets and feeding

Brachiaria grass hay was used as the basal diet while *Acacia tortilis*, sunflower seed cake, hominy meal and mineral mixture were used as components of the supplementary rations. Before formulation of supplementary diets, the actual CP content of *Acacia tortilis*, sunflower seed cake, hominy meal and hay were determined in the DASP laboratory. Four treatment diets based on *Acacia tortilis* and sunflower seed cake as protein supplement were formulated to contain approximately 17% crude protein. The sunflower seed cake-protein in the supplement was replaced by *Acacia tortilis*-protein at the rate of 0, 33.3, 66.7 and 100% to form treatment diets T_1, T_2, T_3 and T_4 respectively (Table 5) . The formulated diets met the requirements for maintenance, growth and anticipated average daily gain of the growing goats. Hominy meal and mineral mixture were included to balance energy and mineral contents of the test diets.

Table 5: Composition of supplementary rations used in experiments 1 and 2 (as %DM)

Feed component	Treatments			
	T_1	T_2	T_3	T_4
Acacia tortilis pods	0.00	18.10	36.23	54.35
Sunflower seed cake	35.60	23.72	11.87	0.00
Hominy meal	62.40	56.18	49.90	43.65
Maclik super	2.00	2.00	2.00	2.00
Total (%)	100.00	100.00	100.00	100.00

3.4 Experiment 1: growth and intake study

3.4.1 Experimental animals and their management

A total of twenty-four female weaner female goats of Dodoma strain (plate 3) were identified using metal ear tags and kept at Magadu Research Farm, in a raised wooden slatted floor house. Their age ranged between 8 and 9 months, with mean initial body weight of 9.71±1.56 kg. The weaners were allocated randomly to four dietary treatments T_1, T_2, T_3 and T_4, in a completely randomized design (CRD) for 90 days under stall-feeding. Each treatment had 6 weaner female goats. On average, animals with equal initial body weight were equally distributed to all treatments. The initial body weight was taken as covariate to correct for its possible effect on the responses. All animals were dewormed using Lavamisole hydrochloride intramuscularly (at a dose rate of 1ml/10kg Bwt) one week before the commencement of preliminary period. The animals were also injected with 1ml of vitamin mixture so as to keep the animals in good health condition. The experimental goats were sprayed with an acaricide (Dominex) fortnightly to control external parasites. The wooden pens were thoroughly cleaned and disinfected before the animals were put into their individual pens to minimise the chances of of microbial and parasitic infections.

3.4.2 Feeding of experimental animals

All animals were subjected to a preliminary period of 14 days to familiarize them to the pens and other experimental conditions. During this period the weaners were fed Brachiaria hay *ad libitum* and 200g per animal per day of supplementary ration which was composed of the average of all four dietary combinations. After this period, animals were provided with their respective dietary treatments for 7 days before the start of data collection as an adaptation period. During actual data collection which lasted for 90 days, feeding regime was designed to provide *ad libitum* amount (200 to 500g) of Brachiaria hay as basal diet. To avoid spoilage, the basal diet was split into two portions, which were fed at 10:00 and 15:30h daily. Water was offered in 4 litre buckets twice per day, and animals were allowed to drink *ad libitum*. Supplementary diets were given to weaner goats at a rate of 20g per kg BW at around 8.30h daily.

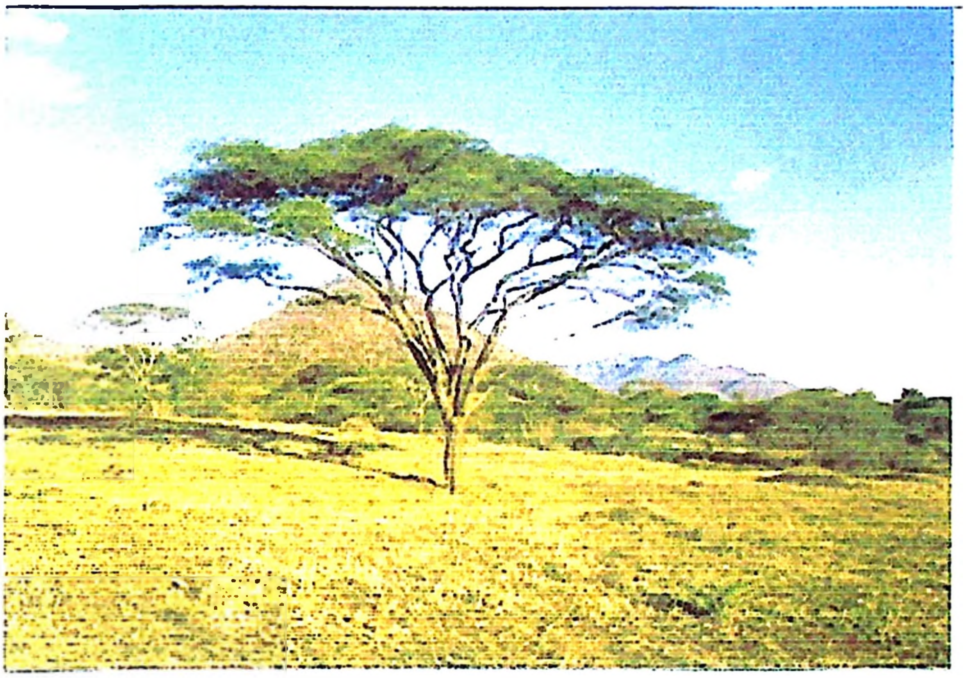

Plate1: *Acacia tortilis* tree in the field

Plate 2: Dried *Acacia Tortilis* pods

Plate 3: Some of the weaner goats used for the growth study

Plate 4: Some of the goats used for the in vivo digestibility study

3.4.3 Liveweight recording and feed intake

Animals were weighed for three consecutive days at the beginning of the experiment. Mean weights for the three days were used as the initial body weights. The same weighing procedure was employed at the end of the experimental period to obtain mean final weights. In between, the animals were weighed once every week. Weighing was done using an electrical digital weighing balance. This exercise was carried out in the morning at 9.30h prior to feeding. Daily growth rate (daily gain) was derived as the difference between the initial body weight and final body weight divided by the number of experimental days. Intake of Brachiaria hay and supplementary rations for each animal were recorded throughout the experimental period. All refusals were collected and recorded at 8:00h every day before a new ration was provided. Samples collected for hay fed and refusals were put in the oven at 60°C for 48 hours for partial dry matter determination. The values were used to estimate dry matter intake (DMI) of Brachiaria hay. Feed DMI (hay) was obtained as the difference between the total hay DM offered and total hay DM refused. The overall feed DMI was obtained by summation of hay DMI and supplement DMI.

3.5 Experiment 2: Digestibility study

Digestibility study was conducted to evaluate the effect of dietary treatments on nitrogen utilization and in vivo digestibility of DM, OM, N and NDF when *A. tortilis* pods was fed to goats.

3.5.1 Experimental animals and treatments

Twelve male goats used in this experiment were dewormed at rate of 1ml using injectable Levamisole hydrochloride just one week before the onset of the experiment. They were also sprayed with Dominex acaricide so as to control external parasites. Before introducing goats to individual metabolic cages, all metabolic cages (see plate 4) and associated equipment were thoroughly cleaned and disinfected. Each goat was placed in a separate metabolic cage fitted with wire mesh and underneath a plastic sheet, to facilitate separate collection of urine and faeces. Each cage was fitted with a hay feeder/trough. Concentrate and watering containers were also fitted. All were detachable to facilitate daily cleaning.

A completely randomized design experiment with the same four treatment diets as those used in the growth and intake study was carried out. Three animals were randomly allocated to each treatment in individual metabolic cages. The animals were subjected to 14-days preliminary period to acclimatize them to the cage environment and the feed. This was followed by total collection period of 8 days. Each animal was given hay allowing refusals of less than 5 – 10%. Rations split into two portions were fed at 0830 and 1530h. Goats were fed 15g/kg Bwt of the supplementary diet at about 1030h and had free access to clean water all the time.

Amounts of feed offered and refused were recorded daily and representative samples were taken and oven dried for dry matter determination.

3.5.2 Collection period

Faeces and urine from each animal were collected daily at 0730h. The volume of urine produced by each animal was measured using a measuring cylinder and recorded. Total urine produced daily by each goat was preserved by adding 20cc of dilute sulphuric acid, and proportionately 10% of the daily excreted urine was sampled, bulked in air tight plastic bottles, pending analysis. Faeces from each goat were collected and weighed daily. After thorough mixing, a 20% sample of the fresh faeces from each goat was put in airtight plastic bags and then stored in a deep freezer at –5°C. At the end of the seven days collection period, the faeces for each goat were thoroughly mixed. About 20% of the fresh sample for each animal were retained for analysis of N-content. The rest was oven-dried at 60°C for 48 hours. The dried faecal samples were ground to pass through a 1mm sieve, subsampled and stored in airtight bottles for chemical analyses.

3.6 sampling and chemical analyses

Before feeding in the morning the refusals were collected, weighed and sampled per individual animal, and oven dried at around 65°C to constant weight for subsequent chemical analyses. Representative samples of feeds offered, refusals and faeces were ground to pass through a sieve size of 1mm.

3.6.1 Dry matter determination

Representative samples of the feed ingredients (SSC, MB, Atp and hay), refusals, supplementary diets and faeces, were weighed (W_1) and pre-dried in the oven at 65°C to constant weight, then reweighed (W_2). The dry matter (DM_1) was determined as:

$DM_1 = W_2/W_1 \times 100\%$

Where:

DM_1 = Dry matter of feeds after drying at about 60°C

W_1 = Weight of samples as fed

W_2 = Weight of samples after drying at about 60°C

The samples were ground through 1mm sieve, then samples of about 1g (W_A) were oven dried at about 105°C to constant weight for 24 hours. The reweighed sample was denoted by W_B. The percent dry matter (DM_2) of the feeds as fed was determined as:

$DM_2 = DM_1 \times W_B/W_A$

Where:

DM_2 = Dry matter of feed sample as fed

DM_1 = Dry matter of feeds after drying at about 60°C

W_A = Weight of pre-dried ground sample

W_B = Weight of the ground sample after drying at about 105°C

NB: The drymatter used in the results was DM_2.

3.6.2 Determination of CP, NDF, ADF, Ash, IVDMD, IVOMD and ME

CP and ash contents of the feeds were determined according to standard analytical procedures of Association of Official Analytical Chemists (AOAC, 1990). Neutral detergent fibre (NDF) and acid detergent fibre were determined by methods as outlined by Van Soest *et al.* (1991). Nitrogen content of fresh faeces and urine were determined by Kjeldahl system according to AOAC (1990).

The energy concentration of each feed ingredient and the concentrate mixture was estimated by the following formula (MAFF, 1975):

ME (MJ/kgDM) = 0.012CP + 0.031EE + 0.005CF + 0.014NFE

Where CP, EE, CF and NFE are in g/kgDM.

To determine ME for the basal diet, the grass hay was subjected to an in vitro technique to determine dry matter digestibility (DMD %) which was then converted to digestible organic matter in the dry matter (DOMD %) by the following formula (MAFF, 1975):

DOMD % = 0.98DMD % - 4.8, ME (MJ/kgDM) = 0.15DOMD %)

3.6.3 *In vivo* digestibility

Apparent digestibility coefficients of DM, OM, CP and NDF were determined as:

$$\frac{A - B}{A} \times 100$$

Where, A = Weight DMI or OMI or CP I or NDF intake respectively

B = Weight of faecal DM, OM, CP or NDF

3.6.4 Growth and feed conversion efficiency determination

Daily growth (daily gain) wasobtained as the difference between the initial body weight and final body weight divided by the number of days the experiment lasted. Feed conversion efficiency was obtained by dividing the daily DMI by daily weight gain.

3.6.5 Nitrogen balance determination

N content of *Brachiaria* hay and supplementary diets was determined so as to determine total N-intake (TNI) which was derived as:

TNI = Total NI in hay + Total NI in supplementary diet

The frozen faecal samples were ground using a small mortar and pestle and subsampled for N determination. Total daily faecal N (TFN) per animal was obtained as:

Weight of faeces x % feed nitrogen

The bulked urine for 8 days per goat was sampled and 1ml taken for %N determination. The obtained value of percent urinary-N in 1ml of urine was converted into content per unit weight of urine (which was recorded during collection period). The total daily urinary-N per animal in grams was obtained as:

TUN (g) = Average daily urine weight (g) x %Urinary N

The total daily N output (TNO) in grams was obtained as:

TNO (g) = TUN (g) + TFN (g)

N-retained (NR) was obtained as the difference between N-intake and N-output as follows

NR (g) = TNI (g) – TNO (g)

3.7 Statistical analyses

3.7.1 Growth and intake study

3.7.1.1 Growth and feed conversion efficiency

Data on growth rate and feed conversion efficiency, were analyzed using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, 1998). The analysis was carried out according to the following statistical model:

$$Y_{ij} = \mu + T_j + b\,(X_{ij} - X) + e_{ij}$$

Where:

Y_{ij} = Observation of the i^{th} animal under j^{th} treatment

μ = Overall mean

T_j = Effect of the j^{th} treatment (supplementary diet) (j: T1=0% Atp, T2=33.3% Atp, T3=66.7% Atp, T4=100% Atp

b = Regression coefficient of response variable on initial body weight

X_{ij} = Initial body weight of individual animal

$\bar{X}$ = Mean initial body weight of all goats in the experiment

e_{ij} = Random error specific to each individual

3.7.1.2 Feed intake

Data on feed intake were analyzed by General Linear Model Programme of SAS (1998). The data were analyzed according to the statistical model:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where:

Y_{ij} = Observation of the j^{th} animal in i^{th} treatment

μ = Overall mean

T_i = Effect of the i^{th} treatment (supplementary diet)

e_{ij} = Random error specific to each individual

3.7.2 Digestibility and nitrogen balance studies

Data on these parameers were analyzed by General Linear Model Programme of SAS (1998). The data were analyzed according to the statistical model:

$$Y_{ij} = \mu + T_i + e_{ij}$$

where:

Y_{ij} = Observation of the j^{th} animal in i^{th} treatment

μ = Overall mean

T_i = Effect of the i^{th} treatment (supplementary diet)

e_{ij} = Random error specific to each individual

3.8 Simple economic analysis on treatment diets

Economic benefits (marginal profit) of substituting SSC with Atp in each treatment was calculated as the difference between revenue from liveweight gain/animal and cost of concentrate consumed/animal. Costs of formulation of the diets were based on the costs of the hominy feed, SSC and Atp. Revenue from liveweight gain/animal in each treatment was obtained by multiplying liveweight gain (kg)/animal by price of liveweight gain/kg. The cost of concentrates consumed (kg/animal) was calculated as amount of concentrate consumed times the cost of each ingredient used in the formulation of treatment diets.

CHAPTER FOUR

RESULTS

4.1 General observations

4.1.1 Health of the experimental goats

There were no signs of illness during both the growth and intake study and all experimental goats gained weight. One goat in treatment one (T_1) died on the third day of preliminary period in the digestibility study. Post-mortem examination of the goat revealed secondary bloat, caused by obstruction of the oesophagus by a polythene bag. Another goat was used to replace the dead goat before commencement of data collection.

4.1.2 Chemical composition and *in vitro* digestibility of feedstuffs and experimental diets

Overall mean values of chemical composition and *in vitro* digestibility of feedstuffs and experimental diets are shown in Tables 6 and 7 respectively.

As expected hay had the lowest level of CP, with its fibres (NDF) and ash content being the highest. Sunflower seed cake (SSC) had the highest CP content followed by *Acacia tortilis* pods (Atp) and hominy meal (HM) whereas hay had the lowest. The *in vitro* digestibilities for sunflower seed cake were lower than for the other feedstuffs. However, the hominy meal (HM) had the highest in vitro digestibilities relative to other feedstuffs.

Supplementary diets had CP values ranging between 16.5 to 17.6%. There were little variations in the rest of the chemical composition amongst the supplementary diets. Generally however, the ash content of the supplementary diets increased gradually as the level of *Acacia tortilis* pods increased in the rations. T_2 had relatively lower NDF and ADF compared to other treatment diets.

Table 6: Chemical composition and *in vitro* digestibility of the individual feedstuffs used in the study (as % DM)

Component	Feedstuffs			
	Hay	SSC	Atp	HM
Composition				
DM	86.2	90.4	86.9	87.6
OM	86.8	95.6	93.2	92.9
Ash	13.2	4.4	6.8	7.1
CP	11.4	23.9	16.4	12.0
NDF	75.2	46.5	39.0	22.0
Digestibility				
IVDMD (%)	56.8	43.5	51.0	78.0
IVOMD (%)	57.9	46.1	51.2	78.4
ME(MJ/kgDM)	7.7	12.6	11.0	13.3

SSC = Sunflower seed cake, Atp = *Acacia tortilis* pods HM = Hominy meal

Table 7: Chemical composition and *in vitro* digestibility of the supplementary rations (as %DM)

Component	Supplementary diets (Treatments)			
	T1	T2	T3	T4
Composition				
DM	90.5	89.4	88.9	87.4
OM	93.4	93.3	92.1	91.7
Ash	6.6	6.7	7.9	8.3
EE	9.5	9.4	7.4	5.9
CP	17.6	17.0	16.5	16.5
CF	21.6	21.2	22.1	18.4
NDF	49.5	39.1	41.1	40.3
ADF	32.8	45.7	46.1	50.9
NFE	44.7	29.5	32.4	30.1
Digestibility				
IVDMD (%)	67.3	64.7	62.07	65.4
IVOMD (%)	68.2	66.9	65.44	66.9
ME (MJ/kgDM)	11.4	12.4	11.83	11.9

4.3 Voluntary feed intake

Least square means for feed DM, CP and metabolizable energy (ME) intake are shown in Tables 8, 9 and 10. Mean intake for individual animals are shown in Appendix 4.

Table 8: Least square means and SEM of DM intake during growth study (Experiment 1)

Parameter	Treatments					
	T1	T2	T3	T4	SEM	SL
Hay (g/d)	145.65^{b}	203.31^{a}	211.69^{a}	236.52^{a}	15.09	**
Supp. Diet (g/d)	184.96	197.14	192.86	193.60	12.48	NS
Total (g/d)	330.61^{b}	400.45^{ab}	404.55^{ab}	430.13^{a}	25.56	*
g/kg $W^{0.75}$	37.92^{b}	41.87^{a}	43.17^{a}	44.61^{a}	1.10	**
As %BW	3.21^{b}	3.58^{a}	3.71^{a}	3.85^{a}	0.11	**

* Means with different superscript within a row differ significantly (P<0.05)

** Means with different superscript within a row differ significantly (P<0.01)

SL= Significant level; NS= Non significant; SEM= Standard error of means

Table 9: Least square means and SEM of CP intake in Experiment 1

Parameter	Treatments					
	T1	T2	T3	T4	SEM	SL
Hay (g/d)	16.54^{b}	23.10^{a}	24.05^{a}	26.87^{a}	1.79	**
Supp. Diet (g/d)	32.51	33.53	31.80	31.98	2.09	NS
Total (g/d)	49.06	56.63	55.85	58.85	3.51	NS
g/kg $W^{0.75}$	10.51	11.15	11.14	11.37	0.29	NS

** Means with different superscript within a row differ significantly (P<0.01)

SL= Significant level; NS= Non significant; SEM= Standard error of means

Table 10: Least square means and SEM of daily energy (ME) intake in Experiment 1

Parameter	Treatments					
ME (MJ)	T1	T2	T3	T4	SEM	SL
Hay	1.15^{b}	1.61^{a}	1.67^{a}	1.87^{a}	0.12	**
Supp. Diet	1.85	1.94	1.83	1.87	0.12	NS
Total	3.00^{b}	3.55^{ab}	3.50^{ab}	3.74^{a}	0.22	*
ME (MJ//kg $W^{0.75}$)	0.47	0.56	0.55	0.59	0.03	NS

* Means with different superscript within a row differ significantly (P<0.05)

** Means with different superscript within a row differ significantly (P<0.01)

SL= Significant level; NS= Non significant; SEM= Standard error of means

Substitution of ground *Acacia tortilis* pods for sunflower seed cake resulted into significantly (P<0.05) higher hay intake and total dry matter intake. Animals in treatment T_1 had lower total dry matter intake compared to those in treatments T_2, T_3 and T4. The highest intake of hay was observed in animals, which were supplemented with diet T_4 followed by T_3 and T_2. Animals supplemented with diet T_1 had the lowest intake of hay.

There was a significant (P<0.01) difference in total dry matter intake (TDMI) based on metabolic weight (g/kg $W^{0.75}$) by animals fed supplementary diet T_1 and those provided with diet T_2, T_3 and T_4. Animals in T_1 had lower TDMI than those in T_2, T_3 and T_4. Intake levels of crude protein ranged from 49.06 to 58.85gd^{-1} (10.51 – 11.37g/kg $W^{0.75}$), whilst total energy intake ranged from 3.00 to 3.74 ME MJd^{-1} (0.47

– 0.59 ME MJ/kg $W^{0.75}$). Total crude protein intake (gd^{-1}) was not significantly ($P>0.05$) different between treatments and a similar trend was observed when expressed on metabolic body weight. However, hay CP intake was significantly ($P<0.01$) higher for animals in treatments 2, 3 and 4 than those in treatment 1. Total energy intake (ME MJd^{-1}) was significantly ($P<0.05$) lower for goat weaners in treatment 1 than those in treatments 4. Similarly, energy intake ME MJd^{-1} was relatively lower for animals in treatment 1 than those in treatment 2 and 3, however the differences were not statistically ($P>0.05$) different.

4.4 Growth performance

Least square means for liveweight parameters measured are shown in Table 11. Individual animal values for initial and final body weights, weight gain, growth rates are shown in Appendix 3.

Initial and final liveweight did not differ significantly ($P>0.05$) between treatments. Total gain and average daily gain differed significantly ($P<0.05$) between treatment diets. The growth rate of animals tended to increase with increasing level of *Acacia tortilis* pods in treatment diets. Control animals (T_1) had significant ($P<0.05$) lower growth rates (g/d) than their counterparts on T_3 and T_4, but did not differ significantly ($P>0.05$) with animals on T_2. The highest daily gains were observed in animals supplemented with diet 3 (2:3 SSC: Atp), but this did not differ statistically from T_2 and T_4. The differences in performance were also reflected in feed conversion efficiency ratio ($P<0.05$). The best growth performance was observed in animals supplemented with diets containing 66.7 and 100% Atp as replacement of

CSC while animals fed supplements without Atp (Control – T_1) had the lowest (19.76g/day) growth rate.

Table 11: Least square means and SEM of growth performance and feed conversion ratio in Experiment 1

Parameter	Treatments					
	T1	T2	T3	T4	SEM	SL
No. of animals	6	6	6	6		
Days in experiment	90	90	90	90		
Initial liveweight (kg)	9.44	9.94	9.58	9.71	0.66	NS
Final liveweight (kg)	11.19	12.37	12.49	12.61	0.77	NS
Weight gain (kg)	1.75^{b}	2.43^{ab}	2.91^{a}	2.90^{a}	0.27	*
Growth rate (gd^{-1})	19.47^{b}	26.63^{ab}	32.02^{a}	31.76^{a}	2.97	*
Feed conversion ratio	18.52^{a}	15.56^{ab}	13.12^{b}	13.53^{b}	1.32	*
Age (days)						
Start	259.66	263.16	256.16	254.16	4.29	NS
End	349.66	353.16	346.16	344.16	4.29	NS
Adjusted means						
Initial liveweight	9.39	9.76	9.66	9.86	0.66	NS
Final liveweight	11.15	12.20	12.57	12.77	0.77	NS
Growth rate (g/d)	17.76b	27.07^{ab}	32.35^{a}	32.04^{a}	3.00	*
Total dry matter intake	339.39b	397.65a	404.84a	423.86a	14.62	*

* Means with different superscript within a row differ significantly (P<0.05)

SL= Significant level; NS= Non significant; SEM= Standard error of means

4.5 *In vivo* digestibility study

4.5.1 Apparent digestibility coefficients

Mean effects of dietary treatments on apparent digestibility coefficients and level of significance are shown in Table 12. Values for digestibility by individual animals are shown in Appendix 5.

Table 12: Least square means and SEM of nutrient digestibility in goats in Experiment 2

Component	Treatments					
	T1	T2	T3	T4	SEM	SL
			Digestibility coeeficients			
DM	63.47	64.32	66.37	67.97	2.14	NS
OM	67.95	68.35	70.49	72.15	1.95	NS
CP	63.17	60.34	62.61	64.25	2.49	NS
NDF	67.17	65.39	64.62	67.66	1.94	NS

SL= Significant level; NS= Non significant; SEM= Standard error of means

The level of inclusion of Atps in supplementary diets had no significant ($P>0.05$) effect on the apparent digestibility of DM, OM, CP and NDF. However there was a tendency for digestibility coefficients of DM and OM to increase with increasing levels of *Acacia tortilis* pods in the supplementary diets. The highest DM and OM digestibility coefficients were observed in animals supplemented with T_4 (100% Atp) while those supplemented with 100% SSC had lowest values.

4.5.2 Nitrogen utilization

Mean effect of dietary treatments on nitrogen utilization is shown in Table 13.

Table 13: Least square means and SEM showing the effect of treatments on nitrogen utilization in goats

Parameter	Treatments					
	T1	T2	T3	T4	SEM	SL
N-intake (g/d)	12.23	11.64	13.23	14.63		NS
N-excreted (g)						
Faecal-N	4.57	4.21	5.10	5.32		NS
Urinary-N	6.79	6.24	6.54	6.48		NS
Total	11.36	10.45	11.63	11.80		NS
N-absorbed (NA)	7.49	7.27	7.88	9.09		NS
N-retained (NR)	0.87	1.19	1.59	2.83		NS

SL= Significant level; NS= Non significant; SEM= Standard error of means

Treatment diets did not significantly (P>0.05) affect nitrogen intake. Likewise the overall nitrogen excretion was not significantly (P>0.05) affected by dietary treatments, however animals which received dietary treatment T_4 had highest nitrogen excretion compared to their counterparts. Similar trend was revealed in the faecal nitrogen excretion. Highest values for NI and NA were observed in animals on T_4. Animals in all treatments showed a positive N-balance.

4.6 Economic analysis

Table 14 shows the economics of treatments imposed in this study. The highest profit margin per liveweight gain (kg) was obtained from animals on T4, followed by those on T3, T2 and T1, respectively.

Table 14: Effect of substituting SSC with Atp on profitability of goats production

	Treatments			
	T_1	T_2	T_3	T_4
Concentrate consumed (kg/animal)	16.3	17.4	17.1	17.1
Cost of concentrate consumed (Tshs/animal)	888.8	896.5	830.1	778.8
Gain in liveweight (kg/animal)	1.75	2.43	2.91	2.90
Revenue from liveweight gain/animal (Tshs. 600/kg)	1050	1458	1746	1740
Marginal profit (Tshs./animal)	161.2	561.2	915.9	961.2

CHAPTER FIVE

DISCUSSION

5.1: General observation

Good health status of goats observed during the entire experimental period, suggest that the use of Atp had no any adverse effect. Further, it implied that all goats were intensively managed and were subjected to routine close examination.

The CP content of the hay used in this study was higher (11.4 %) than that of 4.2 % reported by Katakweba (2002) for similar grass species in Tanzania. The CP content was even far above the critical level of 6-8% at which intake and digestibility could be affected (Van Soest, 1994). Kay and MacDearmid (1973) indicated that a dietary crude-protein content of 11% was ideal for normal weight gain by sheep and goats. However, higher levels of dietary crude protein are required for higher weight gains by goats. This statement is in agreement with reports by Mafwere and Mtenga (1992) who observed that as dietary crude protein level was increased from 11.36 to 13.22, 15 and 16.73%, corresponding growth rates of 34.14, 65.65, 68.01 and 70.5 g/day, respectively, were obtained for weaned lambs fattened on *Chloris gayana* hay and lablab meal as protein supplement. The probable reason for the higher CP content in this study could be that the grass hay was harvested at relatively younger age. It is well documented that differences in stages of maturity of grasses have pronounced effects on nutrient contents as reviewed by Mero and Uden (1998). Furthermore, the hay used by Katakweba (2002) was probably harvested at an advanced stage of maturity. At this stage, the grasses are dry and deficient in nutrient contents (Mero and Uden, 1998). The grass hay had lower values (75.15 %) of cell wall content

(NDF) than those of 79.41 % reported by Katakweba (2002). The season and stage of growth at which the grass hay was cut could have contributed to these differences. The increase of NDF and decrease in protein content as the forage matures have been discussed by Crowder and Chheda (1982), Van Soest, (1994), and McDonald *et al.* (1997). The NDF content of a feed has a very poor correlation to the intake potential due to its rate of passage and digestion (Stensing and Robinson, 1997).

SSC used in this study had a CP content of 23.9% DM which was lower than values reported by Kitalyi (1982) and McDonald *et al.* (1997) ranging from 29.7 to 32.4 % DM for undecorticated SSC. The difference was probably due to the way SSC was processed. The nutritive value of the undicorticated SSC depends on the oil extraction process, the variety of sunflower and the proportion of the hulls removed during processing (Topps and Oliver, 1993; Mandibaya *et al.*, 1999). The CP content in this study was in agreement with results reported by Shayo (1992), Bwire and Wiktorsson (1996) andTemu (2001).

Crude protein level of Atp of 16.4% was within the range of 12.3 to 19.1% reported by several workers. In the studies by Gohl (1981) the minimum of 12.3% was reported while Ngwa *et al.* (2000) reported a maximum of 19.1% for Atp. The CP values of the present study is slightly higher than the one reported by Shayo (1992) working in the semi-arid areas of central Tanzania which was 13.4%. The variations in nutritive value of *Acacia tortilis* pods have been discussed by Gohl (1981) and Coppock *et al.* (1987). These authors reported that region and season are major sources of variation in nutritive value of *Acacia* pods. For instance, Gohl (1981) found that CP content of Atp from Kenya was 17.8%, while those from Tanzania had a CP content of 12.3%. Dougal and Bogdan (1958) reported the CP of Atp collected from the same site in January and February to be 17.8% and 10.4% respectively.

The cell wall constituent (NDF) of the Atp found in the present study of 39.0 was within the range reported by Shayo (1992) and Ngwa *et al.* (2000). Comparatively, SSC had relatively higher values of CP and NDF than that of Atp. Shayo (1992) reported similar findings of higher CP and NDF values in SSC than that of Atp. CP of supplementary rations was almost similar in all treatments (16.5 – 17.6 %). The fibre (NDF) values of SSC were higher than that in the Atp. This resulted in lower fibre (NDF) values in the treatment rations which contained 33.3 %, 66.7 % and 100 % Atp than those of 100 % SSC. The phenomenon had resulted to the decreasing trend of fibre content in the dietary treatments with increasing levels of Atp.

It was noted that all SSC and Atp based diets supplements were highly accepted by goats and were eaten immediately without any refusal. This sugests that all dietary treatments were highly palatable. Generally the goats in all dietary treatments gained weight.

5.2 Feed intake

It was noted that all SSC and Atp based diets supplements were highly accepted by goats and were eaten immediately without any refusal. The feed intake, when expressed as a percentage of liveweight for goats in the tropical environment ranges from 2.5 – 3.9% (Devendra and Burns, 1983). In this study, the daily total DMI was between 330.6 and 430.1g/d, which were approximately between 3.2 and 3.8 % of body weight of the goats, values which are within range reported by Devendra and Burns (1983). The results in the present study was however lower than that reported by Ndemanisho (1996) of 4.0 to 5% body weight for weaner dairy goats on treated maize stover basal diet supplemented with different levels of *Leucaena*. Mtenga and Shoo (1990) reported intakes of between 2.2 and 4.0 % of body weight in goats offered Rhodes grass hay supplemented with *Leucaena* forage. The observed variation in DMI reported by different authors could be attributed to variation beween diets used, mode of feeding and nutritional interaction, breed of goats, climatical differences, level of protein concentration, sex and physiological state of animals used in different experiments.

The observed DMI per day for the growing goats in the present study was consistent with DMI suggested by Kearl (1982) for tropical countries, which varies from 47.4 to 78.5g/kgW0.75 (1.1 to 4.1% body weight). The DMI in this study increased gradually as the level of Atp was increased in the supplementary diet. Animals in T_4 had the highest and T_1 the lowest of DMI among the four treatments. The high total DMI attained by animals on T_4, T_2 and T_3 was probably due to relatively low cell wall (NDF) content in these treatment rations. The lack of significant difference in grass hay intake between the treatments T_2, T_3 and T_4 is an indication that the proportions of pods in the concentrate mixture and sunflower seed cakes had a similar influence on the utilisation of the grass hay. Van Soest (1982) indicated that protein supplementation tends to improve intake by increasing microbial population and also improves the rate of breakdown of digesta. When the rate of breakdown increases, there is a corresponding increase in feed intake.

In this study, intake of CP followed the same trend as for DMI. The CP intake values obtained were slightly higher than the maximum intake of 9.4 g/kgW0.75 reported by Kitalyi (1982). The CP intake reported in this study of 10.5 to 11.4 g/kg$W^{0.75}$) were sufficient for maintenance and growth as suggested by NRC (1989), which are 4.15 gCP/kg$W^{0.75}$ for maintenance and 0.284g/g gain in body weight. According to Preston and Leng (1987) protein supplements increase the supply of nitrogen to the rumen microbes that increase microbial population responsible for breakdown of the digestor resulting into higher passage rate and increased feed intake. Voluntary intake of hay-concentrate diets is usually a function of hay quality, proportion of concentrate in the diet and the concentrate protein level (Crabtree and Williams, 1971). Protein supplementation normally affects roughage DMI through its effect on digestion in the rumen and or through an icrease in the flow of dietary protein to the intestine.

The inferiority in DMI observed in animals supplemented with SSC alone (T_1) could be attributed to relatively high NDF content of the SSC. It is also likely that the high EE content of the SSC negatively affected the rumen environment, thus slowing down the rate of microbial fermentation and hence the reduced DMI. Forbes (1995) noted that the dietary fat seems to interfere with rumen fermentation and that voluntary feed intake is often depressed by high dietary fat. The higher DMI of hay showed by animals supplemented with Atp based diets versus those supplemented with SSC based. This indicates the effect of Atp on the improvement of rumen condition for roughage digestion in the respective animals brought about by inclusion of Atp in their supplementary rations. Ibeawuchi and Yusufu (1990) reported a significant ($P<0.05$) increase in total DMI when *Acacia* pods were incorporated in concentrate supplements. Animals, which were receiving Atp as a sole protein source (T_4) were superior in total DMI than their counterparts supplemented on SSC (T_1) The possible reason could be the difference in fibre contents of Atp and SSC used in making the respective supplements. Atp had lower cell wall (NDF) content than that of SSC. Generally the feeding value of the forages and the extent of forage degradation in the rumen is constrained by the amount of fibre content (NDF) (Aregheore, 2000). Feeds containing high cell wall content show restricted voluntary intake due to their slow degradability and accumulation fiber in the rumen (Yahaya *et al.*, 2000).

The energy intakes varied from 3.00 to 3.74 MJ ME/kgDM for the animals offered the T_1 and T_4 respectively. Animals offered the 100% Atp consumed apparently more energy and this may explain the better weight gains in contrast to those offered 100 % SSC. When energy intake is increased animals retain more either partly as protein if nitrogen intake is adequate, or entirely as fat, and the animals liveweight gain increases. According to McDonald *et al.* (1997), energy intake is the pace maker of production since animals tend to show a continuous response to changes in the quantities supplied.

The linear increase in total DMI was observed as the Atp inclusion levels were increased in the supplement diets. This has an implication to the farmer, that as more Atp is fed to goats voluntary DMI increases, thus goats can eat more of the low quality roughage available during the dry season and perform at optimal level.

5.3 Growth performance

Results on growth performance for T_2, T_3, T_4 were in agreement with those obtained by Shoo (1986) who supplemented (200g/d) to local Tanzania goats (6-7 months) with *Leucaena leucocephala* and obtained average daily gain of 29 ± 4 g/d. The observed values in this study were also lower than those reported by Ndemanisho *et.al.*, (1998) who observed growth rate of 36.4 – 39.4 g/d when cotton seed cake substituted *Leucaena* as protein supplement to urea treated maize stover fed to dairy weaner goats. Whilst Ibeawuchi and Yusufu (1990) observed growth rate of 52.4 – 78.2 g/d when different levels of *Acacia albida* pods were used as protein supplement to weaner goats. The author concluded that incorporation of *Acacia* pods up to 40% of the feed supplement could give the best results interms of intake, growth rate and feed efficiency. Growth rates observed in this study were however higher than those reported by Ayo (2002) when used similar breed of goats and observed growth rates of 19.7 – 25.1g/d when cotton seed cake was replaced by waste brewers' yeast at different levels. This suggests that among other factors, levels of supplementation and nature of feed used in supplementation have a significant influence on growth performance.

Significantly lower growth rate in goats supplemented with SSC as plant protein than their counterparts fed Atp based diets observed in the present study could be partly due lower energy and CP intake. Level of energy intake together with protein: energy ratio, have been considered to be critical in the performance of growing goats (Mtenga and Madsen., 1992). An increase of protein intake on low levels of energy intake have been found to provide no improvement in growth performance (Muhikambele, 1990), while increasing intake of energy, growth rate increased as well as requirement for protein intake. Muhikambele (1990) recorded lower growth performance (27g/d) for goats with low energy intake (5.1 ME MJ/d) and medium protein level (45g DCP/d).

Several other factors attributes to variability in growth performance as reported by various authors such as quality of basal ration (Preston and Leng, 1987). Rate of growth in goats could be attributed to breed differences and nutritional management. Growth performance in the present study indicated that all goat weaners on Atp supplemented diet gained weights which were not statistically ($P>0.05$) different, but the significant ($P<0.05$) differences in weights gain were observed when compared to goats on 100 % SSC supplement diet. Comparatively goats fed on 100 % SSC supplement showed the least weight gain. It was however, found that the effect of 100 % Atp in supplement diet on growth performance was relatively more pronounced than that of mixture between SSC and Atp when fed to weaner goats. This effect suggests that Atp may solely replace the SSC as protein supplement on grass hay basal diet for weaner goats. These results agree with those reported by

Temu (2001) when SSC was replaced by *Morus alba* as protein supplement at different levels to weaner goats.

According to Devendra and McLeroy (1982) maintenance energy requirement for goats weighing between 10 and 20kg ranges from 3.25 – 5.47 MJ ME/d. The observed energy intake values in this study for animals which were receiving T_2, T_3 and T_4 were within this range, while those goats supplemented on T_1 was relatively below the range. Consequently, animals in T_1 had lower weight gain than in other treatments (19.5g/d versus 31.8g/d). The observed results in the former can partly be due to differences in feed intake by the respective animals of which the same animals had the lowest values. The low growth performance could also be contributed to an effect of high fat content of the SSC which interfere the rumen ecosystem leading to reduction in microbial fermentation and therefore, poor release of nutrients for biological synthesis.

Data on feed conversion ratio (FCR) with significantly higher values for animals supplemented solely with SSC, also indicated that these animals utilised feed less efficiently and hence their slower growth rates. Shahjalal *et al.* (1992) found that optimum levels of both protein and energy intake are important for better feed utilization efficiency in which case high energy, high protein dietary combinations produced better results than those with either less protein or energy relative to requirements. Feed conversion ratios and their related growth rate are influenced by many factors like sex, age, health status of the animal, breed and composition of the gain.

Proper supplementation is achieved only if the range diet and supplemented feed combine properly to supply the required nutrients. Thus a small amount (100 – 300g/d) of high protein feed is usually adequate (Church, 1991). This might be cause of non- significance in growth perfomance between the animals supplemented Atp based diets (T_2, T_3 and T_4) such that the three supplements supplied similar amounts of energy and protein to the animals. In this regard, this indicates that the proportions of *Acacia* pods in the concentrate mixture and sunflower seed cakes had a similar influence on the utilisation of the grass hay. The difference in growth between T_1 and the rest of the treatments could be due to the fact that the supplements T_2, T_3, and T_4 were a source of by-pass protein and energy, thus improved the rumen environment by making available nitrogen, minerals and soluble carbohydrates for efficient microbial synthesis (Chenost and Kayouli, 1997; Payne and Wilson, 1999) resulting in improved digestibility of the basal diet from supplementary diets. Lower growth rate observed in T_1 compared to other treatments could also be due to the decreased efficiency of utilisation rather than low feed intake alone. On the other hand, the differences in the proportions of bypass protein could further explain the phenomenon. It is likely that T_1 supplements had more rumen degradable and less bypass protein compared to the other supplements. Higher liveweight gains have been reported when animals are supplemented with forages rich in bypass protein (Abdulrazak *et al.*, 1996).

5.4 *In vivo* Digestibility

5.4.1 Apparent digestibility coefficients

Nutrient digestibility coefficients in the four diets were statistically similar across the treatments. Ayo (2002) observed similar trend for goats fed low quality hay supplemented with different levels of waste brewers' yeast and cotton seed cake. The apparent digestibility coefficients for DM (63.5-68.0%) and OM (68.0-72.0%) were relatively similar to those reported by Veereswara Rao *et al.* (1992) and Ondiek *et al.* (2000). When supplemented dairy goats fed *Rhodes* grass hay based diet with legumes and commercial concentrates, Ondiek (2000) observed DM coefficients of the order 61.5 to 72.0%.

Digestibility coefficients for DM, OM and NDF observed in the present study are however relatively higher than those reported by Orden *et al.* (2000) for ammonia treated rice straws supplemented with *Leucaena* and *Gliricidia* leaves. It was also higher than the findings by Sarwatt *et al.* (2000) when *Moringa* leaf meal and sunflower seed cake fed in combination with low quality hay for goats. Except for NDF, nutrient digestibility coefficients increased although not significantly ($P>0.05$) with increasing level of *Acacia tortilis* pods in the diets. In this case, animals receiving SSC (100 %) and Atp (100 %) supplement only had similar coefficients for NDF (67.2 - 67.7 %).

Despite the apparently similar digestibility in the four treatments, the growth performance of goats offered T_1 was lower than their counterparts. This was possibly due to their significant ($P < 0.05$) low mean total DMI and mean total energy intake compared to their counterparts. Furthermore the lower gains observed for goats in T_1 relative to their counterparts in other treatments was due to low efficiency in utilisation of the absorbed nitrogen. The observed insignificant differences in DM, OM, CP and NDF digestibility coefficients of the total rations for all treatment groups, implied that all treatment rations met the necessary requirement for protein and energy for microbial digestion. Muhikambele et al. (1993) reported that, although the level of protein in the diet influences intake, digestibility and overall feed utilisation efficiency in livestock, the effect of protein on performance depends on the balance of other nutrients particularly energy in the case of ruminants.

5.4.2 Nitrogen utilization

It has been established that the N-retained for tissue requirement is a function of N-intake (Kitalyi, 1982). The values of N intake observed in this study were lower than those reported by Ayo (2002) for goats fed low quality grass hay supplemented with waste brewers' yeast and cotton seed cake of 27.2-36.6 % and Murro (2002) for sheep fed low quality *Rhodes* grass hay supplemented with *Moringa* and cotton seed cake of 20.8-30.5 %. The higher level of N excreted via urine in both treatments suggests that less amount of it was retained in the body of the animal, and thus less N was recycled back to rumen. Also a higher loss of N through urine is associated with feeding highly degradable protein that contributes largely to the ammonia pool. If the animal requirement is met, excess of it is recycled to the rumen or removed via urine (Tamminga and Verstegen, 1991). Nature of proteins has been reported to influence N excretion and retention. This has been associated among other to the degradability characteristics of the protein source as suggested by Reed, *et al.* (1990).

Goats fed on T_4 (100% Atp) retained slightly higher N relative to the N absorbed than the other treatments. Differences in N retention between animals receiving similar levels of dietary protein have been observed by Chowdhury *et al.* (1995) in which case positive N-balances were associated with moderate to high levels of energy intake.

Animals fed low quality roughage supplemented with protein rich concentrates are likely to have low nitrogen retention and high urinary nitrogen excretion (Ownwuka and Akinsoyinu, 1989). Rumen microbes require readily available energy for growth and efficiently absorb the fermentable N. In the presence of low diet metabolisable energy, multiplication and hence absorption of N in the rumen dwindle. Unabsorbed N should undergo transamination and diamination to supply the energy deficit or excreted and render N less utilized.

Urinary N-loss was relatively higher than faecal-N for all the treatment diets. It is suggested that N utilisation may be related to the quality of absorbed protein as reported by Osuji *et al.* (1993). Reed *et al.* (1990) studied a variety of indigenous or locally available legumes as supplements of Teff straw. The supplements were fruits of *Acacia sieberiana*, leaves of *Acacia seyal*, *Sesbania sesban*, *Vicia dasycarpa* hay and Nough cake (*Guizotia abyssinica*). They all promoted positive nitrogen balances but the authors suggested that the N fraction in the diets containing *Acacias* had a reduced availability as a result of the influence of polyphenols on protein digestion. Onwuka and Akinsoyinu (1989) observed that if high protein diets are fed, breakdown of protein usually exceeds microbial protein synthesis leading to high levels of ammonia in the rumen, which is absorbed into the blood, carried to the liver and excreted in urine. Riis (1983) observed that high protein intakes with low energy levels lead to increased urinary N excretion and attribution of amino acid and consequently higher urinary N excretion. The elevated proportion of nitrogen appearing in the urine and feaces of goats fed on both treatment diets as reflected in less nitrogen retention is suggestive of a greater extent of formation of ammonium and other related non-protein nitrogenous substances in the rumen and hind gut which were absorbed and subsequently lost via the kidney and undigested protein.

The N supplied by each treatment ration seems to have exceeded the animal requirement for maintenance since a positive N balance was observed in all animals during the experiment. The four dietary treatments were statistically not different in terms of N intake, excreted N, absorbed N and retained N. This implied that respective supplement sources and levels were of relatively similar potential for use as protein supplements in ruminant nutrition.

5.5 Economic analysis

The estimate costs of the supplements indicated that the Atp based supplements (T_2, T_3 and T_4) were cheaper than SSC based supplement (T1) and therefore resulted in higher profit margins over supplementation. SSC is an expensive component because of being diverted to cities for use on peri-urban dairy farms and compounding poultry feeds. These factors contribute to the high cost of convetional commercial concentrate. The decreased monetary value of Atp based diet decreased progressively as the level of Atp was increasing in the diet. Similary the liveweight gain increased as the level of Atp increased in the supplement diets. This may have an implication for goats fed Atp based diet to reach target weight earlier due to increased growth rate than those on SSC based diet.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1Conclusion: The following conclusions were made

1. Owing to the availability and free access to Atp during the dry season, the use of Atp will be more convinient, practical and adaptive by livestock keepers in the central regions of Tanzania in particular Dodoma.

2. Growth rate of weaner goats increased with increasing level of inclusion of *Acacia tortilis* pods as a substitute of sunflower seed cake.

3. *Acacia tortilis* pods can safely substitute SSC up to 100 % without affecting performance of weaner goats. Substitution of SSC with Atp gave positive results in weaner goats' performance especially in terms of DMI of the grass hay and growth performance.

4. Costs were reduced and marginal profit was increased as Atp inclusion was increased in the dietary treatments.

6.2 Reccommendations

1. It will be of interest to repeat the study taking into account more animals per treatment and animals of different physiological states such as pregnant and lactating goats.

2. It would be also of interest to compare subsitution value of Atp in terms of biological and economic values to other protein sources such as forage legumes and other oil seed cakes.

REFERENCES

Abdulrazak, S.A., Muinga, R.W., Thorpe, W and Orskov, E.R. (1996). The effects of supplementation with *Gliricidia sepium* or *Leucaena leucocephala* forage on intake, digestion and live-weight gains of *Bos taurus X Bos indicus* offered napier grass. *Journal of Animal Science* 63: 381 - 388.

Abunie, B.B. (1992). Productive and reproductive performance of Tanzania Indigenous Goats and their Crosses with Kamorai and Boer. M.Sc. Dissertation. Sokoine University of Agriculture, Morogoro, Tanzania, 175pp.

Ademosun, A.A. (1974). Utilization of poor quality roughages in the derived savanna zone. In: *Animal Production in the Tropics*. Improvement of *Pennisetum purpureum* Schum. (Edited by Loosli J.K. et al.) pp. 32 – 40.

Ademosun, A.A., Bosman, H.G and Jansen, H.J. (1988). Nutritional studies with West African Dwarf goats in the Humid tropics. In: Goat production in the Humid tropics. (Edited by Smith, O.B. and Bosman, H.G.). Pudoc Wageningen, Netherlands. pp 51 – 61.

Aganga, A.A.; Ummuna, N.N. and Chineme, C.N. (1983). Requirement and utilization of nitrogen by ruminants. A Review. *Journal of Animal Production Research* 3: 139 – 154.

Allen, V.G. and Segarra, E. (2001). Anti-quality components in forage: Overview, significant and economic impact. *Journal of Range Management* 54: 409 – 412.

ARC. (1980). Agricultural Research Council.The nutrient requirements of ruminant livestock. Commonwealth Agricultural Bureaux, Farnham Royal. pp. 351.

ARC. (1990). The nutrient requirement of ruminant livestock. Forth Edition. CAB International Walling ford, UK. pp. 73 – 310.

AOAC (1990). Association of Official Analytical Chemists. *Official Methods of Analysis*. AOAC. Washington D.C. pp. 69 – 88.

Aregheore, E.M. (2000). Chemical composition and nutritive value of some tropical by-product feedstuffs for small ruminants *in vivo* and *in vitro* digestibility. *Animal Feed Science and Technology* 85: 99 - 109.

Ash, A.J. (1990). The effect of supplementation with leaves from the leguminous trees *Sesbania grandiflora*, *Albizia chinensis* and *Gliricidia sepium* on the intake and digestibility of guinea grass hay by goats. *Animal Feed Science and Technology* 28: 225 - 232.

Atta- Krah, A.N. and Sumberg, J.I. (1988). Studies with *Gliricidia sepium* for crop/livestock production system in West Africa. *Agroforest Systems Journal* 6: 97 - 118.

Ayo, E.M. (2002). The use of waste Brewers' Yeast (WBY) as a protein supplement for growing Tanzania goats fed low quality hay. M.Sc. Dissertation, Sokoine University of Agiculture, Morogoro, Tanzania, pp. 87-112.

Ayoade, J.A. and Butterworth, M.H. (1982). The relationship between birth and weaning weight in kids of Malawi local goats, Boer and their crosses. *Tropical Animal Production* 7: 113 – 115.

Banualim, A., Stachiw, S., Jones, R.J. and Murry, R.M. (1984). The effect of fresh *Leucaena leucocephala* as a supplement on the utilisation of pasture hays by goats. Proceedings of the *Australian Society of Animal Science* 15: 259-262.

Bhattacharya, A.N. (1989). Characteristics of Adhi goats in Saudi Arabia. *Small Ruminant Research* 2: 217 – 224.

Barry, T.N and Reid, C.S.W. (1984). Nutritional effects attributable to condensed tannins, cyanogenic glycosides and oestrogenic compounds in New Zealand forages. In: *Forage Legumes for Efficient Animal Production. (Edited by Barnes, R.F. et al.)* USDA ARS, CSIRO, DSIR. pp. 246 - 250.

Beddinga, T and Degefa, G. (1990). Working document No 14, Trends in Agro-byproducts and their feeding potential in Sub-Sahara Africa. http:// [www.fao.org/wairdocs/ilri/x5480e/x5480e03.htm] site visited on 5/6/2002.

Berhanu, B., Mtenga, L.A. and Kifaro, G.C. (1992). Pre-weaning and post-weaning growth performance of the small East African goat and its Crosses. *Bulletin of Animal Production in Africa* 41: 81 – 87.

Bhattachrya, A.N. and Hussain, F. (1974). Intake and utilization of nutrients in sheep fed different levels of roughage under heat stress. *Journal of Animal Science* 38: 877 – 886.

Bitende, S.N. and Ledin, I., 1994. The voluntary intake and digestibility by sheep fed on two levels of low quality grass hay supplemented with *Acacia tortilis* fruits or *Sesbania sesban* leaves. Paper 1. In: The potential of *Acacia tortilis* fruits and *Sesbania sesban* leaves as livestock feeds in smallholder farming systems. Bitende, S.N. (1994). M.Sc. Dissertation. Department of Animal Nutrition and Management, SUAS, Uppsala, Sweden, pp. 1-10.

Bonsi, M.L.K. and Osuji, P.O. (1997). The effect of feeding cotton seed cake, Sesbania or Leucaena with crushed maize as supplement to teff straw. *Livestock production Science* 51: 173 – 181.

Baumont, R. (1996). Palatability and feeding behaviour in ruminant. *Annales de Zootechnies* 45: 385 - 400.

Bradford, G.E. and Berger, Y.M. (1988). Breeding strategies for small ruminant in arid and semi-arid areas. In: *Increasing Small Ruminant Productivity in Semi-arid Areas. (Edited by Thomson, E.F. and Thomson, F.S.)*. ICARDA, Syria. pp. 95 – 109.

Bradifield, P.G.E. (1968). Sex differences in the growth of sheep. In: *Growth and Development of Mammals. (Edited by Lodge, G.A. and Lamming, G.E.)*. Butterworths, London. pp. 92 – 108.

Bray, R.A., Jones, R.J and Probert, M.E. (1984). Shrub legumes for forage in tropical Australia. In: *Shrub Legume Research in Indonesia and Australia. (Edited by Craswel E.T. l and Tangendjaja B)*, ACIAR, Canberra. pp. 33 - 38.

Brenan, J.P.M. (1983). Manual on Taxonomy of *Acacia* species: Present taxonomy of four species of *Acacia* (*A. albida, A. senegal, A. nilotica, A. tortilis*). FAO, Rome, Italy. 47 pp.

Bwire, J.M.N and Wiktorsson, H (1996). Pre-weaning nutritional management and dry season nutritional supplementation on intake, growth and onset of puberty of improved Zebu heifers. *Journal of Livestock Production Science* 46: 229 - 238.

Bwire, J.M.N and Wiktorsson, H. (2002). Effect of level of *Acacia tortilis* and Acacia*Faidherbia albida* pods supplementation on the milk quality of dual-Purpose dairy cows fed grass hay-based diets. Paper V. In: *Feeding strategies for dual-purpose cattle in semi-arid areas of central Tanzania.* Bwire, J.M.N. (2002). Ph.D. Thesis. Department of Animal Nutrition and Management, SUAS, Uppsala, Sweden, pp. 1-12.

Challya, J.N. (1998). Physics and genetic characterisation of three strains of goat in Tanzania. MSc. Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania, pp. 80 – 114.

Charray, J., Humbert, J.M. and Levis, J. (1992). Manual of sheep in humid tropics of Africa. CAB International, Wallingford, UK. 187 pp.

Chate, C.G. (2001). Effect of on-farm dry season supplemetation of Boer goat crosses on growth and lactation. M.Sc. Swedish University of Agricultural Sciences, Uppsala, Sweden, pp. 1 – 10.

Chenost, M and Kayauli, C. (1997). Roughage Utilisation in Warm Climate. FAO Animal Production and Health Paper 135. pp. 101-162.

Chowdhury, S.A., Hovell, F.D. DeB., Orskov, E.R., Scaife, J.R., Mollison, G and Borongo, S. (1995). Protein utilization during energy undernutrition in sheep sustained on intragastric infusion: Effect of changing energy supply on protein utilization. *Small Ruminant Research* 18: 219 – 226.

Church, D.C. (1991). Livestock Feeds and Feeding. 3rd Ed. Prentice Hall, New Jersey. pp 101-176.

Coppock, D.L., Swift, D.M., Ellis, J.E. and Waweru, S.K. (1987). Seasonal nutritional characteristics of livestock forage in Southern Turkana. *East African Agriculture and Forestry Journal* 53 (3): 162 – 175.

Crabtree, J.R. and Williams, G.L. (1971). The voluntary intake and utilization of roughage – concentrate supplements for hay and straw. *British Animal Production Journal* 13: 71 – 82.

Crowder, L.V. and Chheda, H.R. (1982). Tropical Grasslands Husbandry. Longman, London. 562pp.

D'Mello, J.P.F. (1992). Chemical constraints to the use of tropical legumes in animal nutrition. *Animal Feed Science and Technology* 38: 237 - 361.

Das, S.M., Bee, J.K.A., Said, R. and Sendalo, D.S.C. (1989). Early growth performance of meat goats in the semi-arid region of Northern Tanzania. In: *Proceedings of the sixteenth Scientific Conference of the Tanzania Society of Animal Production*. (Edited by Kurwijila, L. et al.). 26 – 28 September 1989, AICC, Arusha Tanzania, pp 12 – 19.

Das, S.M. and Sendalo, D.S. (1990). Comparative performance of improved meat goats in Malya, Tanzania. In: *Proceedings of the First African Small Ruminant Research Network. Bienniall Conference and General Assembly.* (Edited by Rey, B. et al.). 10 – 14 December 1990, ILRAD, Nairobi, Kenya. pp. 445 – 452.

Das, S.M and Sendalo, D.S. (1991). Small ruminant Research Highlights in Tanzania (1960-1989). Ministry of Agriculture, Livestock Development and Co-operatives. Department of Research and Training, Dar es Salaam, Tanzania. pp. 10 - 16.

Devendra, C. and McLeroy, G.B. (1982). *Goat and Sheep Production in the Tropics.* Intermediate Tropical Agricultural Series Longman Group Ltd, Harlow, Essex, UK. 271pp

Devendra, C. (1983). Tree leaves for feeding goats in humid tropics. In: *Proceeding of World Animal Production Conference. Tokyo, Japan*. 2: 543-544.

Devendra, C. and Burns, M. (1983). *Goat Production in the Tropics*. Second edition. Commonwealth Agricultural Bureau, Slough, UK. 183pp

Devendra, C. (1986). Feeding systems and nutrition of goats and sheep in the tropics. In: *Proceedings of the Workshop on the Improvement of Small Ruminants in Eastern and Southern Africa.* (*Edited by* Aneniji, K.O. and Kategile, J.K.). 8 – 12 August 1986. Nairobi, Kenya, pp 35 – 40.

Devendra, C. (1987). Goats In: *An Introduction to Animal Husbandry in the Tropics (Edited by Williamson, G. and Payne, W.J.A),* Longman Group Ltd, London, UK. 463pp.

Devendra, C. (1988). Forage supplements: Nutritional significance and utilisation for drought, meat and milk production in buffaloes. In: Proceedings of The Second World Buffalo Congress. Vol.2, 12-16 December 1988, Indian Council of Agricultural Research, New Delhi, India. ICAR, New Delhi, pp. 409 - 423.

Devendra, C. (1990). The use of shrubs and tree fodders by ruminants. In: *Shrubs and Tree Fodders for Farm Animals. (Edited by Devendra, C.) International Development Research Centre,* IDRC-276e, Ottawa, Canada. pp.42 - 60.

Devendra, C. (1991). The non-conventional feed resources in Asia and the Far East. APHCA/FAO, Bangkok. pp. 10 – 11.

Dougall, H.W. and Bogdan, A.V. (1958). Browse plants of Kenya with special reference to those occurring in South Baringo. *East African Agriculture Journal* 23: 236 – 245.

Dzowela, B.H., Hove, L., Maasdorp, B.V and Mafongoya, P.L. (1997). Recent work on the establishment, productin and utilisation of multipurpose trees as a feed resource in Zimbabwe. *Animal Feed Science and Technology* 69: 1-15.

Ebong, C. (1994). *Acacia nilotica*, *Acacia seyal* and *Sesbania sesban* as supplements to tef (Eragrostis tef) straw fed to sheep and goats. *Small Ruminant Research* 18: 233-238.

Egan, A.R. (1977). Nutritional status and intake regulation in sheep. VII. Relationship between voluntary intake of herbage by sheep and the protein/energy ratio in the digestion products. *Australian Journal of Agricultural Research* 28: 907 – 915.

Egan, A.R. (1986). Principles of supplementation of poor quality roughages with nitrogen. In: *Ruminant Feeding Systems Utilizing Fibrous Agricultural Residues: International Development Programme of Australian Universities and Colleges Limited (IDP), (Edited by Dixon R.M)*, Canberra, A.C.T. pp.49-57.

FAO, (1998). Tropical Feeds version 8. File:///D:/DOCS/TFEED8/DATA/554.HTM.

Farvedin, P., Baumont, R. and Ingvartsen, K.L. (1995). Control and prediction of feed intake in ruminants. In: Proceedings of The Forth International Symposium on the Nutrition of Herbivores, Recent Developments in the Nutrition of Herbivores, INRA Editions, Paris pp 95 - 120.

Fedele, V., Pizzillo, M., Claps, S., Morand – Fehr, P and Rubino, R. (1993). Grazing behaviour and diet selection of goats on native pasture in Southern Italy. *Small Ruminant Research* 11: 305 - 322.

Forbes, J.M. (1986) The voluntary Food Intake of Farm Animals. Butterworths Co. Ltd. London. pp. 67-81.

Forbes, J.M. (1995). *Voluntary Food Intake and Diet Selection in Farm Animals.* CAB International, New York. 132pp

Firsch, J.E. and Vercoe, J.E. (1978). Utilizing breed differences in growth of cattle in the tropics. *World Animal Review* 25: 8 – 12.

Gall, C. (1996). Goats breeds of the world. CTA-Margraf, Weikersheim. 67pp.

Gathuka, Z.G. (1986). Management of small ruminant production systems in the farming areas of Kenya. In: *Proceedings of the workshop on the improvement of small ruminants in Eastern and Southern Africa.* (Edited by Adeniji, K.U and Kategile, J.K.). Nairobi, Kenya. pp 195 – 205.

Gebrelul, S.; Leon, S.; Sartin III and Ihenacho, M. (1994). Genetic and non-genetic effects on the growth and mortality of Alpine, Nubian and Crossbred kids. *Small Ruminant Research* 13: 169 – 176.

Girdhar, N., Lall, D and Pathak, N.N. (1991). Effect of feeding Leucaena leucocephala as the sole ration on nutrient utilisation and body weight in goats. *Journal of Agricultural. Science* 116: 303 - 307.

Göhl, B. (1981). *Tropical Feeds, Feed Information Summaries and Nutritive Values.* FAO, Rome. Animal Production and Health Series 12: 320-322.

Goodchild, A.V. and McMeniman, N.P. (1994). Intake and digestibility of low quality roughages when supplemented with leguminous browse. *Journal of Agricultural Science* 122 (1): 151 – 160.

Gordon, I.J. (1995). Animal based techniques for grazing ecology research. *Small Ruminant Research* 16: 203 - 214.

Goromela, E. H. (1996). Digestibility in goats of leaves from three indigenous trees common in Central Tanzania Paper II. In: The influence of indigenous browse and other local feeds on the milk production and nutrition of dual-purpose goats in Central Tanzania. MSc Thesis. Department of Animal Nutrition and Management, SUAS, Uppsala, Sweden. pp 1 – 10.

Grossman, C.J. (1985). Interaction between the gonadal steroids and the immune system. *Journal of Animal Science* 227: 257 – 261.

Grovum, N.M and Phillips, G.D. (1978). Factors affecting the voluntary intake of food by sheep. The role of distension, flow rate and propulsive motility of the intestines. *British Journal of Nutrition* 40: 323 - 336.

Gupta, J.P., Rao, G.G., Gupta, G.N. and Rao, B.V.R. (1983). Soil drying and wind erosion as affected by different types of shelter belts planted in the desert region of Western Rajastan. *Indian Journal of Arid Environments* 6 (1): 53 – 58.

Gwyne, M.D. (1969). The nutritive values of *Acacia* pods in relation to Acacia seed distribution by ungulates. *East African Wildlife Journal* 7: 176 – 178.

Hafez, E.S.E. (1968). Adaptation of Domestic Animals. Washington State University press, Pullman, Washington, United States of America. 415pp.

Hagos, M., Samucisson, G., Kenne, L., and Modawi, B.M. (1987). Isolation of smooth muscle relaxing 1,3-diaryl-propan-2-ol derivatives from *Acacia tortilis*. *Planta Medica* 53(1): 27 - 31.

Hofs, P., Montasma, G. and Nabnurs, S. (1984). Growth and reproduction rates of West African dwarf goats under different levels of feeding and management. In: Sheep and goats production. ILCA, Addis Ababa. pp 25 – 28.

Hutchison, J.E. and Shelton, M. (1971). An evaluation of various protein concentrates for growing finishing lambs. *Animal Science* 32: 334 – 338.

Ibeawuchi, J.A and Yusuf, A.A. (1990). Effect of various levels of dry Acacia albida pods in concentrate supplement for goats: Growth response and feed intake. *Bulletin of Animal Health and Production. Africa* 38: 219 - 222.

ILCA. (1981). Trends and Prospects for Livestock and Crop Production in Tropical Africa. *Working Document Number 5*. ILCA, Addis Ababa, Ethiopia. pp. 13 – 16.

ILCA. (1987). ILCA Annual Report for 1987. International Livestock Centre for Africa, Addis Ababa, Ethiopia. pp. 20 – 34.

ILCA. (1992). Annual Report and Programme Highlights. International Livestock Centre for Africa. Addis Ababa, Ethiopia. 86pp.

Inou'e, T., Brookes, I.M., John, A., Kolver, E.S and Barry, T.N. (1994). Effects of leaf shear breaking load on the feeding value of perennial ryegrass (Lolium perenne) for sheep. 2. Effects on feed intake, particle breakdown, rumen digesta outflow and animal performance. *Journal of Agricultural Science* 123: 137-147.

James, R.S and Phylo, E. (1984). Livestock development in sub-saharan Africa. Constraints, prospects and policy. A West-View Replica, Edition. pp. 110-112.

Jones, R.J. (1979). The value of *Leucaena leucocephala* as a feed in the tropics. World Animal Review, 31: 13 – 23.

Jones, R.J., Meyer, J.H.F., Bechaz, M. and Stoltz, M.A. (2000). An approach to screening potential pasture species for condensed tannin activity. *Animal Feed Science and Technology* 85: 269 – 277.

Kamalzadeh, A., Koops, W.J., Van Bruchem, J. (1998). Effect of the duration of feed restriction of feed intake, nitrogen and energy balance. In: *Regulation of Feed Intake. (Edited by Vander Heid, D., Huisman, E.A., Osse, J.W.M., Verstegen, M.W.A.),* Wageningen, Netherland. pp. 22 – 27.

Kapembe, S.F. (2002). Effect of deworming regime on growth performance of grazing small East African Goats. M.Sc. Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania. pp. 32 – 33.

Karua, S.K. and Banda, J.W. (1990). Dairy goat breeding in Malawi. Gestation length, birth weights and growth of indigenous Malawi goats and their Saanen crosses. In: *Small Ruminant Research and Development in Africa* (*Edited by Rey, B.; Lebbie, S.H.B. and Reynolds, L.*). ILCA, Nairobi, Kenya. pp. 453 – 459.

Karue, C.N. (1974). The nutritive value of herbages in semi-arid lands of East Africa: Chemical composition. *East African Agricultural and Forestry Journal* 40: 89 - 95.

Kassahun, A.; Yibrah, Y. and Fletcher, I. (1989). Productivity of purebred Adal and quarter bred Saanen-Adal goats in Ethiopia. In: *Small Ruminant Research and Development in Africa* (*Edited by Wilson, R.T. and Melaku, I.*). ILCA, Addis Ababa, Ethiopia. pp. 510 – 523.

Kasuku, A.A. and Tibaijuka, B. (1987) Antihelmintic resistance of *Haemonchus contortus* strain in sheep and goats at SUA. In: *Proceedings of the Fifth Tanzania Veterinary Association, Scientific Conference.* (Edited by Msolla, P. et al). 9 – 11 December 1987, AICC, Arusha, Tanzania, pp. 193 – 216.

Katakweba, A.A.S. (2002). Development of weaner meal for dairy calves using fish wastes nile perch (*Lates niloticus*) and cassava (*Manihot esculenta*) root meal. M.Sc Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania, pp. 92 – 93.

Kay, M. and McDearmid. (1973). A note on the effect of changing the concentration of protein of the diet offered to fattening beef cattle. *Animal Production* 12: 323 – 334.

Kearl, L.C. (1982). Nutrient requirements of ruminants in developing countries. Agriculture Experiment Station, State University, Logan, Utah 84322 USA. pp 59-66.

Kenny, P.A and Black, J.L. (1984). Factors affecting diet selection by sheep. 1. Potential intake rate and acceptability of feed. *Australian Journal of Agriculture Research* 35: 551-563.

Khalili and Varvikko, T. (1992). Effect of replacement of concentrate mixture by wilted Sesbania (Sesbania seaban) forage on diet digestibility, rumen fermentation and milk production in Friesian X Zebu (Boran) crossbred cows fed low quality native hay. *Animal Feed Science and Technology* 36: 275 – 286.

Kiango, S.M. (1996). Studies on Factors Affecting Performance of Dairy Goats and on Socio-economic Aspects of Dairy Goat Production in Tchenzema and Dareda Wards in Tanzania. M.Sc. Dissertation. Sokoine University of Agriculture, Morogoro, Tanzania. 184pp.

Kimambo, A.E. (1985). Nutritive Penalties Associated with Subclinical Infection of Lambs with the Intestinal Round Worms, *Trichostrongylus colubriformis*. Ph.D. Thesis. The Rowett Research Institute. Bucksburn Aberdeen, UK, 197 pp.

Kimambo, A.E., Jecha, M.A. and Aboud, A.A. (1989). The use of "Kangara pombe" wastes and *Leucaena leucocephala* as supplement to growing young Goats. In: *Proceedings of the sixteenth Scientific Conference of the Tanzania Society of Animal Production.* (Edited by Kurwijila, L. et al.). 26 – 28 September 1989, AICC, Arusha Tanzania, pp 103 – 108.

Kimbi, E.F.C. (1997). The effect of substituting Leucaena luecocephala for cotton seed cake as protein supplement for urea treated maize stover on performance of goat weaners. M.Sc. Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania, pp. 69 – 72.

Kitalyi, A.J. (1982). Effects of Supplementing Low Quality Hay with Different Protein Level on Growth Performance of Goats. M.Sc. Dissertation. University of Dar es Salaam, Tanzania, 157pp.

Kiwuwa, G.H. (1992). Breeding strategies for small ruminant productivity in Africa. In: *Proceedings of the First Biennial Conference of the African Small Ruminant Research Network.* (Edited by Rey, B. et al.). 10 – 14 December 1990. ILCA, Nairobi, Kenya. pp. 423 – 434.

Kyomo. M.L. (1978). Meat From Goats in Tanzania. Ph.D. Thesis. University of Dar es Salaam, Tanzania, 272 pp.

Lamprey, H.F. (1967). Notes on the dispersal and germination of some tree seeds through the agency of mammals and birds. *East African Wildlife Journal* 5: 179 - 180.

Laredo, M.A. and Minson, D.J. (1975). Effect of pelleting on voluntary intake and digestibility of leaf and stem fractions of three grasses. *British Journal of Nutrition* 33: 159 – 170.

Lebbie, S.H.B. and Manzin, A.T. (1989). The productivity of indigenous goats under traditional management in Swaziland. In: Small Ruminant Research and Development. (Edited by Wilson, R.T. and Maluku, A.). ILCA, Addis Ababa, Ethiopia. pp 39 – 50.

Leek, B.F. (1986). Sensory receptors in the ruminant alimentary tract. In: *Control of Digestion and Metabolism in Ruminants. (Edited by Millingan, L.P. Grovum W.L. and Dobson A)* Pretize – Hall, Englenwood Cliff, N.J. pp. 35-39.

Le Houerou, H.N. (1978). The role of shrubs and trees in the management of natural grazing land with particular reference to protein production. Paper presented at the Eighth World Forestry Congress held in Jakarta, Indonesia, 16-28 October 1978. FFF/10-0. FAO, Rome, Italy. 24pp.

Le Houerou, H.N. (1980). Role of browse in the sahelian and Sudanian zones. In: *Browse in Africa- The Current State of Knowledge (Edited by Le Houerou, H.N.)*, ILCA, Addis Ababa, Ethiopia, pp. 247 - 253.

Le Houerou, H.N. (1980a). Browse in Northern Africa. In: Browse in Africa. (Edited by Le Houerou H.N), ILCA, Addis Ababa, pp. 55-82.

Le Houerou, H.N. (1980b). Chemical composition and nutritive value of browse in tropical West Africa. In: *Browse in Africa (Edited by Le Houerou H.N.)* ILCA, Addis Ababa, pp. 127 – 135.

Leng, R.A. (1997). Tree foliage in ruminant nutrition. FAO Animal Production and Health Paper No. 139. FAO. Rome. pp 37 – 42.

Leng, R.A., Choo, B.S. and Arreaza, C. (1992). Practical Technologies to optimize feed utilization by ruminants. In: *Legume Trees and Other Fodder Trees as Protein Sources for Livestock.* (Edited by Speedy, A. and Pugliese, P.). pp. 75 - 93.

Liu, J.X., Jun Yao, B., Yan, J.Q.Yu and Shi, Z.Q. (2001). Effects of Mullerry leaves to replace rape seed on performance of shep feeding on ammoniated rice straw diet. *Small Ruminant Research* 39: 131 – 136.

Lyons, T.; Caffrey, P.J. and O'Connell, W.J. (1970). The effect of energy, protein and vitamin supplementation on the performance and voluntary intake of barley straw by cattle. *Animal Production* 12: 323 – 334.

Madsen, A. and Mtenga, L.A. (1988). Performance of Norwegian-Tanzania crossed dairy goats in small holder husbandry systems introduced in upper Mgeta: Preliminary results. In: *Proceedings of The Fifteenth Scientific Conference of Tanzania Society of Animal Production.* (Edited by Kurwijila, L. et al). 27 – 30 September 1988, AICC, Arusha Tanzania, pp 140 – 158.

Madsen, A., Nkya, R., Mtenga, L.M. and Kifaro, G.C. (1990). Dairy goats for small scale farmers: Experiences in Mgeta highlands. In: *Proceedings of the seventeenth Scientific Conference of the Tanzania Society of Animal Production.* (Edited by Kurwijila, L. et al.). 25 – 27 September 1990, AICC, Arusha Tanzania, pp 48 – 57.

Madubi, M.A. (1997). Physical characterization of three strains of small East African goats in Tanzania. M.Sc. Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania, pp. 50 - 68.

MAFF (1975). Ministry of Agriculture, Fisheries and Food. Energy allowances and feeding systems for ruminants. *Technical Bulletin* 33: 62 – 67.

Mafwere, W.D. (1991). Evaluation of Lablab Bean (*Dolichos lablab*) Meal as a Source of Protein Supplement for Lambs during the Dry Season. M.Sc. Dissertation. Sokoine University of Agriculture, Morogoro, Tanzania, 131pp.

Mafwere, W.D and Mtenga, L.A. (1992). Lablab (Dolichos lablab) meal as protein supplement for weaned fattening lambs. In: *Proceedings of the first biennial Conference of the African Small Ruminant Research Network.* (Edited by Rey, B. etal.). 10 – 14 December 1990, ILRAD, Nairobi Kenya. ILCA, Addis Ababa, Ethiopia. pp 375 – 386.

Makkar, H.P.S. and Becker, K. (1998). Do tannins in leaves of trees and shrubs from African and Himalayan regions differ in level and activity? *Agroforestry Systems* 40: 59 – 68.

MALD. (1989). Livestock Development Programme 1989-2000. Main Report Sub-sector Summaries, Ministry of Agriculture and Livestock Development, Dar es Salaam, pp 39 - 40.

Mandibaya, W., Mutisi, H., Hamudikuwandu, H and Titterlor, M. (1999). The nutritive value, intake, digestibility and nitrogen balance of farm-grown and preparedsunflowerbased dairy calf meals. *Tropical Animal Health and Production* 31: 321-331.

Marsico, G., Vicenti, A., Contuducanti, P. and Braghieri, A. (1993). Influence of weaning age on reproductive performance of kids slaughtered at 107 days of age. *Small Ruminant Research* 12: 312 – 328.

Martin, LC., Ammerman, C.B., Henry and Loggins, P.E. (1981). Effect of level and form of supplemental energy and nitrogen on utilization of low quality roughage by sheep. *Journal of Animal Science* 53: 479 – 488.

Matovelo, J.A., Semuguruka, W.D., Mella, P.N.P. and Mwamengele, G.L.M. (1987). Some indications on the animal disease status in Tanzania. In: *Proceedings of the fifth Scientific Conference of the Tanzania Veterinary Association.* (Edited by Msolla, P. et al.). 1 – 3 December 1987, AICC, Arusha Tanzania, pp 151 – 163.

Mbise, A.N., Nyange, J.F.C. and Mbasha, E.M.S. (1984). An outbreak in wildlife in Lake manyara National Park, Tanzania. In: *Proceedings of The Second Scientific Conference of the Tanzania Veterinary Association.* (Edited by Msolla, P. et al.). 3 – 5 December 1984, AICC, Arusha Tanzania, pp 126 – 139.

Mboera, L.E.G. and Kitalyi, J.I. (1992). Disease of small ruminant in Central Tanzania. In: *Proceedings of The Second Biennial Conference of The African Small Ruminant Research Network* (Edited by Rey, B. et al). 7 – 11 December 1992. ILCA, Addis Ababa, Ethiopia. pp. 117 – 120.

McDonald, P., Edwards, R.A., and Greenhalge, J.F.D. (1997). *Animal Nutrition*. Fifth Edition. Longman, Singapore Publishers. ELBS. 689pp.

McDowell, R.E. (1968). Climate versus man and his animals. Nature, 218:641.

McGregory, V.D. (1979). Effect of Dietary Protein Level upon Protein Utilization by Weaned Male Holstein Calf. DAI 39: 11, 516IB.

McGregor, B.A and Hodge, R.W. (1988). Growth and production of lactating Australian Feral Does and their Angola cross kids when fed Oats with Urea or Lucern chaff. *Small Ruminant Research* 1: 195 – 201.

Mchau, K.W. (1979). Influence of Boer goat for crossing with Tanzanias goats, Msc. Thesis. University of Dar es Salaam, Tanzania. pp. 126-159.

McMeniman, N.P., Elliot, R and Ash, A.J. (1988). Supplementation of rice straw with crop byproducts. I. Legume straw supplementation. *Animal Feed Science Technology* 19: 43-53.

Mero, R.N. (1985). The effect of supplementing Rhodes grass (*Chloris gayana)* with Siratro (Macroptilium atropurpureum) on dry matter digestibility and voluntary intake. M.Sc. Thesis, Sokoine University of Agriculture, Morogoro, Tanzania. pp. 80 - 90.

Mero, R.N. and Uden, P. (1998). Promising tropical grasses and legumes as feed resources in Central Tanzania. V. Effect of supplementing *Cenchrus ciliaris* hay with leaves from four legumes on intake and digestibility by growing Mpwapwa bulls. *Animal Feed Science and Technology* 70: 111 – 122.

Minson, D.J. (1971). The digestibility and voluntary intake of six varieties of Panicum. *Australian Journal of Experimental Agriculture and Animal Husbandry* 11: 18 - 25.

Minson, D.J and Milford, R. (1967). The voluntary intake and digestibility of diets containing different proportions of legume and mature Pongola grass (*Digitaria decumbens*). *Austrarian Journal of Agriculture and. Animal Husbandry* 7: 546 - 551.

MAFS. (2001). Ministry of Agriculture and Food Security. Basic data-Agriculture Sector 1993/94-1999/2000. Ministry of Agriculture, Dar-es-Salaam, Tanzania; December 2001. pp. 44 – 45.

Mohd, Y., Sulaiman, A.W. and Othman, A.S.H. (1988). Comparative pre-weaning growth rate performance of crossbred kids. *Malaysian Veterinary Journal* 7: 29 – 36.

Morand-Fehr, P. (1981). Growth. In: *Goat Production (Edited by Gall, C).* Academic Press. London. pp. 253 - 283.

Morand – Fehr, P. (1989). Goat nutrition and its particularities in the dry subtropics. In: Ruminant Nutrition in the dry subtropics: Constraints and potentials. EAAP Public. No. 38. CAPD, Wageningen. pp 201 – 206.

Mosi, A.K and Butterworth, M.H (1985a). The voluntary intake and digestibility of diets containing different proportions of Tef (Eragrostis tef) straw and *Trifolium tembense* hay when fed to sheep. *Tropical Animal Production* 10: 19 - 22.

Mosi, A.K and Butterworth, M.H. (1985b). The voluntary intake and digestibility of combinations of cereal crop residues and legume hay for sheep. *Animal Feed Science and Technology* 12: 241 - 251.

Moss, R. (1991). Diet selection- an ecological perspective. *Proceedings of the Nutrition Society,* 50: 71 - 75.

Mourad, M. (1993). Reproductive performance of alpine and zaraibi goats and growth of their first cross in Egypt. *Small Ruminant Research* 12: 379 – 384.

Mtenga, L.A. (1979). Meat production from Saanen goats, growth and development. PhD Thesis. University of Reading, U.K. pp.163 – 181.

Mtenga, L.A. (1986). The feeding of sheep and goats in Tanzania (Research experience). In: *Proceedings of the Workshop on the Improvement of Small Ruminants in Eastern and Southern Africa. (Edited by Adeniji, K.O. and Kategile, J.A.).* 18 – 22 August 1986. pp. 135 – 143.

Mtenga, L.A. (1992). Beef production in the Tropics –Growth-Development and Marketing of Beef Cattle. Teaching notes, Sokoine University of Agriculture, Tanzania, pp. 25 – 45.

Mtenga, L.A. and Kiango, S.M. (1992). Factors affecting performance of dairy goats and their crosses at Sokoine University Farm: Preliminary results. *Journal of Zimbabwe Society of Animal Production* pp. 15: 105 – 109.

Mtenga, L.A. and Madsen, A. (1992). Experience in protein supplementary feeding of weaned lambs and goats in Tanzania: The issue of dietary energy. In: *Proceedings of the First Biennial Conference of the African Small Ruminant Research Network.* (Edited by Rey, B. et al.). 10 – 14 December 1990, ILCA, Nairobi, Kenya. pp. 387 – 399.

Mtenga, L.A. and Shoo, R.A. (1990). Growth rate, feed intake and feed utilization of small East African goats supplemented with *Leucaena Leucocephala*. *Small Ruminants Research* 3: 9 – 18.

Mtenga, L.A., Mandarin, G.C.H., Kitalyi, A.J. and Sarwatt, S.V. (1984). Impact of past and current research on small ruminant meat production in Tanzania. In: *Proceedings of The Eleventh Scientific Conference of The Tanzania Society of Animal Production*. pp. 117 – 119.

Mtenga, L.A., Muhikambele, V.R.M., Mafwere, W.D. and Lock, A.L. (1995). The effect of dry season supplementation with lablab (Dolichos lablab) meal on killing-out characteristics and carcass composition of BHP lambs. In: *Proceedings of the Twenty-second Scientific Conference of Tanzania Society of Animal production*. (Edited by Kurwijila, L and Muhikambele, V.R.). 15 – 17 August 1995, AICC, Arusha Tanzania, pp 78 – 92.

Muhikambele, V.R.M (1990). Protein and mineral supplementattion to growing goats on pasture. M.Sc Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania. pp. 73-89.

Muhikambele, V.R.M and Urio, N.A. (1988). The effect of substituting kapok oil cake with dried leucaena leaves in concentrate rations on the apparent digestibility of Brachiaria brizantha hay by sheep. In: *Improved dairy production from cattle and goats in Tanzania*, NORAGRIC, Norway. pp. 44 –55.

Muhikambele, V.R.M., Mtenga, L.A., Ekern, A. and Owen, E. (1993). Protein and Mineral Supplementation to Growing Goats on Pasture Improved Dairy Production from Cattle and Goats in Tanzania. Part III Reports from Research Projects 1987 – 1992. NORAGRIC Agricultural University of Norway. pp. 32 – 43.

Muinga, R.W., Topps, J.H., Rooke, J.A and Thorpe, W. (1995). Effects of supplementation with Leucaena leucocephala and maize bran on voluntary food intake, digestibility, liveweight and milk yield of Bos indicus X Bos taurus dairy cows and rumen fermentation in steers offered Pennisetum purpureum ad libitum in the semi-humid tropics. *Animal Science* 60: 13 - 23.

Mukasa-Mugerwa, E., Bekele, E. and Tesema, T. (1986). Productivity of indigenous sheep and goats in the Ada District of the Ethiopia Highlands. In: *Proceedings of the Workshop on the Improvement of Small Ruminant in Eastern and Southern Africa* (Edited by Adeniji, K.U. and Kategile, J.K.). ILCA, Nairobi, Kenya. pp 73 – 80.

Murro, J.K (2002) The effects of substituting *Moringa oleifera* leaf meal for cotton seed cake as a protein supplement on feed intake, growth performance and digestibility of low quality hay using sheep weaners. M.Sc Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania, pp 41 - 49.

Ndemanisho, E.E. (1996). The use of *Leucaena leucocephala* (Lam) De wit forage as a feed supplement for dairy goats. Ph.D. Thesis, Sokoine University of Agriculture, Morogoro Tanzania,358pp.

Ndemanisho, E.E., Mtenga, L.A., Kimbi, A.E., Kimambo, A.E and Mtengeti, E.J. (1998). Substitution of dry *Leucaena leucocephala* (DLL) leaves for cotton seed cake (CSC) as a protein supplement to urea treated maize stover fed to dairy weaner goats. *Animal Feed Science and Technology* 73: 365 - 374.

Ndlovu, L.R and Sibanda, L.M. (1996). Potential of *Lablab purpureus* and *Cacia tortilis* pods in smallholder goat kid feeding systems in semi-arid areas of South Africa. *Small Ruminant Research* 21: 273 - 276.

Ngatia, T.A., Kimberling, C.V., Johnson, L.W., Whiteman, C.E. and Lauerman, L.H. (1989). Experimental pasteurellosis in goats. *Bulletin of Animal Health and Production in Africa* 37: 13-19.

Neuman, A.L. (1977). *Beef Cattle.* Seventh edition. John Wiley and Sons, New York. pp. 482 – 522.

Nguyen, T.M., Ledin, I., Uden, P. and Van Binh, D. (2002). The foliage of Fleminga (*Fleminga macrophylla*) or jackfruit (*Artocarpus heterophyllus*) as a substitute for rice bran – Soya bean concentrate in the diet of lactating goats. *Asian-Australian Journal of Animal Sciences* 15 (1): 45 – 54.

Ngwa, A.T., Nsahlai, I.V and Bonsi, M.L.K. (2000). The potential of legume pods as supplements to low quality roughages. *South African Journal of Animal Science* 30: 107-108.

Nherera, F.V., Ndlovu, L.R and Dzowela, B.H. (1998). Utilisation of Leucaena diversifolia, *Leucaena esculenta*, *Leucaena palida* and *Calliandra calothyrsus* as Nitrogen supplements for growing goats fed maize stover. *Animal Feed Science and Technology* 74: 15-28.

Norton, B.W. (1984). Nutrition of the goat: A review. In: *Goat Production and Research in Tropics* (*Edited by Copland, J.W.*). ACIAR Proceeding. Series 7: 75 – 81.

NRC. (1989). Nutrient requirement of goats. National Academy of Sciences. Washington, D.C. pp. 47 – 52.

Nyange, B.G.L. (1994). Studies on the performance of lactating ewes and weaned lambs as influenced by concentrates supplementation. M.Sc. Dissertation. Sokoine University of Agriculture, Morogoro, Tanzania, pp. 70 – 87.

Ondiek, J.O., Tuitoek, J.K., Abdulrazak, S.A., Barceba, F.B and Fujihara, T. (2000). *Asian-Asian-Austrarian Journal of Animal Science* 13(9) 1249 - 1254

Orden, E.A., Abdulrazak, S.A., Cruz, E.M., Orden, E.M., Ichinohe, T and Fujihara, T. (2000). *Leucaena leucocephala* and *Gliricidia sepium* supplementation in sheep fed with Ammonia treated Rice strwa: Effects on Intake, Digestibility, Microbial protein Yield and Live-Weight Changes. *Asian-Austrarian Journal of Animal Science 13(12) 1659 - 1666.*

Ownwuka, C.F.I and Akinsoyinu, A.O. (1989). Protein and energy requirements for maintenance and gain by West African Dwarf goats fed cassava (*Manihot utilissima*) leaves with peels as supplement. *Small Ruminants Research* 2: 291 – 298.

Orskov, E.R and Ryle, M. (1990). Energy Nutrition in Ruminants. Elsevier Applied Sciences, London and New York. 149pp.

Osuji, P.O., Sibanda, S. and Nsalhai, I.V. (1993). Supplementation of maize stover for Ethiopian Menz sheep: Effect of cotton seed cake, nough cake (*Guizotia abyssinica*) or sunflower cake with or without maize on the intake, growth, apparent digestibility, nitrogen balance and excretion of purine derivatives. *Animal Production* 57: 429 – 436.

Paterson, R.T., Karanja, G.M., Roothaert, R.L., Nyaata, O.Z. and Kariuki, I.W. (1998). A review of tree fodder production and utilization within smallholder agroforestry systems in Kenya. *Agroforestry Systems* 41: 181 – 199.

Payne, W.J.A and Wilson, T.R. (1999). An introduction to Animal Husbandry in the Tropics. Blackwell Science, Oxford, pp 447 – 466.

Pellew, A.R. (1980). The production and composition of *Acacia* browse and its potential for animal protein production. In: *Browse in Africa. The current state of knowledge. Papers presented at the International symposium on Browse in Africa. (Edited by Le Houerou, H.N.), ILCA,* Addis Ababa, Ethiopia. April 8-12, 1980. pp. 223 – 230.

Pereka, A. E.(1991). The effect of high ambient temperature and growth hormone on glucose metabolism, blood flow rate and milk synthesis in mammary gland of goats. Ph.D. Thesis, Royal Veterinary and Agricultural University, Copenhagen, pp. 76 –93.

Peters, K.J. and Deichert, G. (1984). Pattern of goat production in low-income. Economic units of Peninsula Malaysia. *World Animal Review* 51: 44 – 50.

Piasentier, E., Bovolenta, S., Mallosini, F. and Susmel, P. (1995). Comparison of n-alkane or chromium oxide methods for estimation of herbage intake by sheep. *Small Ruminant Research* 8: 27 – 32.

Poppi, D.P., Minson, D.J. and Ternouth, J.H. (1981b). Studies of cattle and sheep eating leaf and stem fractions of grasses. The voluntary intake digestibility and retention time in the reticulorumen. *Australian Journal of Agricultural Research* 32: 99 – 108.

Pralomkarn, W., Kchapakdee, S., Saithanoo, S. and Norton, B.W. (1995). Energy and protein utilisation for maitenance and growth of Thai native ansd Anglo X Nubian Thai male weaner goats. *Small ruminant Research* 16: 13 – 20.

Preston, T.R. (1987). Conference summary and overview. In: *Feed Intake by Beef Cattle (Ed. F.N. Owens)*, pp. 387 – 391.

Preston, T.R. and Leng, R.A. (1987). *Matching Livestock Production Systems to Available Resources* in the Tropics and Sub-tropics. Penambul Books, New South Wales. pp. 93 – 123.

Provenza, D.F. and Ropp, J. (2001). Understanding herbivore response to anti-quality factors in forages. *Journal of Range Management* 54: 431 – 440.

Ranjhan, S.K. (1980). Animal Nutrition in the Tropics. Vikas Publishing House PVT. Ltd. Vikas House, 2014, Industrial Area, Sahibabad. DL, Ghaziabad, UP (India), pp. 296 –309.

Ravindra, K. and Vaithiyanathan, S. (1989). Occurrence, nutritional significance and effect on animal productivity of tannins in tree leaves. *Journal of Animal Feed Science and Technology* 30 (1990). pp. 21 – 38.

Reed, D.J. (1995). Nutritional toxicology of tannins and ralated polyphenols in forage legumes. *Journal of Animal Science* 73: 1516 – 1528.

Reed, J.D.; Soller, H. and Woodward, A. (1990). Fodder tree and stover diets for sheep: Intake, growth, digestibility and the effects of the phenolics on nitrogen utilization. *Animal Feed Science and Technology* 30: 39 – 50.

Reed, J.D., Krueger, C., Rodriguez, D. and Hanson, J. (2000). Secondary plant compounds and forage evaluation. Forage Evaluation in Ruminant Nutrition (Edited by Givens et al.). CAB Iternational, Wallingford, pp. 95 – 111.

Refsgaard, H.A. (1978). Effect of energy level in growth and efficiency. In: *Pattern of Growth and Development in Cattle* (*Edited by De Boer, H. and Martin, J.*). Ghent. pp. 395 – 412.

Reynolds, L. (1981). Nitrogen metabolism in indigenous Malawi goats. *Journal of Agricultural Sciences* 96: 347 – 351.

Reynolds, L. (1986). Small ruminant production- the present situation and the possible nutritional interventions for improvement. *ILCA Bulletin*. pp.13–16.

Riis, P.M. (1983). The pools of tissue contituents and products: Proteins. In: *Dynamic Biochemistry of Animal Production. (Edited by Riis, P.M)* Elsevier Science Publisher, Amsterdam, The Netherlands. pp. 75 – 108.

Rhind, S.M. (1992). Nutrition. Its effect on reproduction performance and its hormonal control in female sheep and goats. In: *Progress in sheep and goats Research*. (Edited by Speedy, A.W.). L.A.B. International Washington, U.K. pp 25 – 51.

Romney, D.L. and Gill, M. (2000). Intake of forages. Forage Evaluation in Ruminant Nutrition (Edited by Givens et al). CAB International, Wallingford. pp. 43 – 62.

Rosales, M. and Gill, M. (1997). Tree mixtures within integrated farming systems. Livestock Research for Rural Development, 9 (4) [http://www.cipav.org.co/Irrd/Irrd9/4/mauro941.htm]. site visited on 12/5/2002.

Roy, A.D., Kaul, R.N. and Gyanchand. (1973). Israel babool-a promising tree for arid and semi-arid lands. 147pp.

Sarwatt, S.V. (1989). Feed intake, growth rate and digestibility coefficients of growing sheep fed hay supplemented with *Crotalaria ochroleuca. Animal Feed Science and Technology* 28 (1990) 51 – 59.

Sarwatt, S.V., Kapange, S.S. and Kakengi, A.M.V. (2000). The effects on intake, digestibility and growth of goats when sunflower seedcake is replaced with Moringa oleifera in supplements fed with Chloris gayana hay. In: *Proceeding of the twenty seventh Scientific Conference of Tanzania Society of Animal Production.* (Edited by Mbaga, S.H. et al.). 3 – 5 August 2000, UCLAS-Dar es Salaam, Tanzania, pp 79 – 87.

SAS. (1998). *Statistical Analysis System. SAS / STAT User's guide.* Statistical Analysis Institute, Inc; Cary, NC. USA.

Schneider, B.H. and Flatt, W.P. (1975). *Evaluation of Feed through Digestibility Experiments*. University of Georgia Press, Athens. pp. 94 – 98.

Shafie, M.M., Murad, H.M., El-Bedawy, T.M. and Salem, S.M. (1994). Effect of heat stress on feed intake, rumen fermentation and water turnover in relation to heat tolerance response by sheep. *Egyptian Journal of Dairy Science* 63: 1749 – 1754.

Shahjalal, M., Galbraith, H. and Topps, J.H. (1992). The effect of changes in dietary protein and energy on growth, body composition and mohair fibre characteristics of British Angora goats. *Animal Prodution* 54: 405 – 412.

Sharma, T.C (1979). Efficiency of feed utilisation in goats. In: Proc. Of Summer Institute on Goat Production. Central Institute for Research on goat, ICAR. UP, India, pp. 223 –240.

Shayo, C.M. (1992). Evaluation of water melon as source of water, and water melon seeds and Acacia Pods as prottein supplement for dairy cows in central Tanzania. M.Sc. Thesis, 1992. Department of Animal Nutrition and Management, SUAS, Uppsala, Sweden. pp. 4 – 89.

Shayo, C.M. (1998). Browse leaves and pods as ruminant feed in central Tanzania. Doctoral thesis, Swedish University of Agricultural Sciences. Uppsala. pp.25 – 26.

Shayo, C.M. and Udén, P. (1997). Comparison of water melon (Citrus vulgaris) seed meal, Acacia tortilis pods and sunflower seed cake supplements in central Tanzania, 2. The effect of hay intake and milk yield and composition of Mpwapwa cows. *Tropical Grassland* 31: 130 – 134.

Sheik, M.I. (1982). Performance of some exotic *Acacias* in Pakistan. *Pakistan Journal of Forestry* 32 (3): 108 – 109.

Shelton, H.M. (2001). Advances in Forage Legumes: Shrub Legumes. Paper presented at the 19th International Glassland Congress, 10 – 12 February 2001, Sao Pedro, Brazil. pp. 23 – 29.

Shkolnik, A., Maltz, E. and Gordin, S. (1980). Desert conditions and goat milk production. *Journal of Dairy Science* 63: 1749 – 1754.

Shoo, R.A. (1986). A Comparative Study of Roughage Utilization and Growth Performance Between Sheep and Goats Supplemented with Different Levels of Leucaena leucocephala. M.Sc. Dissertation. Sokoine University of Agriculture, Morogoro, Tanzania. 208 pp.

Sighn, V.B., Mehra, V.R., Sinha, A.P. and Srivastava, V.S. (1991). Effect of planes of nutrition on nutrients utilization and growth on cross-bred calves. *Indian Journal of Dairy Science* XLIV 5:305 – 308.

Singh, S.P., Mukherjee, D.K., Prasad, B and Mishra, H.R. (1981). Note on body measurements and weights of black and brown-bengal goats. *Indian Journal of Animal Science* 51: 234 – 236.

Smith, A.J and Magembe, S.R. (1986). Factors limiting animal production in the tropics. *In: Proceedings of the Fourth Tanzanian Veterinary Association Scientific Conference.* (Edited by Msolla, P. et al.). 2 - 4 December, 1986. AICC, Arusha Tanzania, pp 8 – 24.

Smith, D. (1973). The non-structural carbohydrates. In: *Chemistry and Biochemistry of Herbage. (Edited by Butler, G.W. and Bailey, R.W.)* Academic Press, London. pp. 105-151.

Stanton, T. (1982). Introduction and acceptance of goats and their Socio-economic importance in the Caribbean and Central America. In: Proceedings of the Third International Conference on Goat Production and Disease. 10 – 15 January 1982. Tucson, Arizona U.S.A. pp 182 – 185.

Stensing, T and Robinson, P.H. (1997). Digestion and passage kinetics of forage fibre as affected by fibre-free concentrate in the diet. *Journal of Dairy Science* 80:1339 – 1351.

Stewart, J and Simons, A.J. (1994). Gliricidia sepium a multipurpose forage tree legume. In: *Forage tree legume in tropical agriculture.* (Edited byGutteridge, R and Shelton, H.M) CAB International, pp. 30 - 48.

Tamminga, S and Verstegen, M.W.A (1991) Protein nutrition and animal production: Consequences for environment and some possible recommendations. *Proceedings of the international Symposium on protein Metabolism and Nutrition.* Herning, Denmark. 9 - 14 June, 1991. pp 98 – 109.

Tanner, J.C.; Reed, J.D. and Owen, E. (1990). The nutritive value of fruits (pods with seeds) from four Acacia spp. compared with extracted noug (Goizotia abbyssinica) meal as supplements to maize stover for Ethiopian highland sheep. *Animal Production* 51 (1): 127 – 133.

Temu, V.W.K. (2001). The use of Mulberry (Morus alba) Dry leaves as a protein supplement for Tanzania blended goats fed with low quality roughage. M.Sc. Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania, pp. 60 – 78.

Thomke, S. and Macha, A. (1986). Chemical composition of selected Tanzanian concentrate feedstuffs. Uppsala and Dar-es-Salaam. pp 3-5.

Thorton, R.F. and D.J. Minson. (1973). The relationship between apparent retention time in the rumen, voluntary intake and apparent digestibility of legume and grass diets in sheep, *Austrarian Journal of agricultural Research* 24: 889 – 98.

Tomkins, N.W., McMeniman and Daniel, R.C.W. (1991). Voluntary feed intake and digestibility by red deer (Cervus elephus) and sheep (Ovis ovis) of Pangola grass (Digitaria decumbens) with or without a supplement of leucaena (Leucaena leucocephala). *Small Ruminant Research* 5: 337 – 345.

Topps, J.H. (1992). Potential, composition and use of legume shrubs and trees as fodder for livestock in the tropics. *Journal of Agricultural Science.* Camb 118: 1 – 8.

Topps, J.H. and Oliver, J. (1993). Animal Foods of Central Africa. *Zimbabwe Agricultural Journal 23:* 31 – 33.

Van Eys, J., Matius, I., Pongspan, P., John, and W.L. (1986). Foliage of the tree legumes. *Gliricidia, Leucaena* and *Sesbania* as supplement to Napier grass diet for growing goats. *Journal of Agricultural Science* 107: 227 – 233.

Van Soest, P.J. (1982). *Nutritional Ecology of the Ruminants.* O and B Books Inc., Corvallis, Oregon, USA. 374pp.

Van Soest, P.J. (1988). Effect of environment and quality of fibre on nutritive value of crop residues. In: *Proceedings of a Workshop on Plant Breeding and Nutritive Value of Crop Residues.* (Edited by Reed, J.D. et al.) ILCA, Addis Ababa, Ethiopia. pp. 123 – 130.

Van Soest, P.J. (1992). Nutrition Ecology of the Ruminants. O & B Books. Inc. Corvallis, OR. pp 16-45.

Van Soest, P.J. (1994). *Nutritional Ecology of the Ruminants.* Second edition. Cornell University Press. 373pp.

Van Soest, P.J., Robertson, J.B. and Lewis, B.A. (1991). Methods for dietary fibre, neutral dtergent fibre and a non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583 – 3597.

Veereswara Rao, B., Parthasarathy, M and Krishna, N. (1992). Effect of supplementation with tree leaves on intake and digestibility of hybrid napier (NB-21) grass in Nellore Brown sheep. *Animal Feed Science and Technology* 44: 265-274.

Viengsavanh, P and Inger, L. (2001). Performance of growing goats fed Panicum maximum and leaves of Gliricidia sepium Paper 1. In: The potential of Gliricidia sepium as a feed for goats in small holder farming systems in Lao.

M.Sc. Thesis 2001, Department of Animal Nutrition and Management, SUAS, Uppsala, Sweden, pp 1-10.

Wagner, D. (1989). Strategies to improve performance of growing cattle through protein supplements. *Agricultural Proceedings* 10: 27 – 32.

Webb, R. (1988). A preliminary investigation into the fodder qualities of some trees in Sudan. *International Tree Crops Journal* 5: 9 – 17.

Webster, C.C. and Wilson, P.N. (1980). *Agriculture in the Tropics*. ELBS/Longman, England. pp. 497 – 506.

Weltzin, J.F and Coughenour. (1990). Savanna tree influence on understory vegetation and soil nutrients in northwestern Kenya. *Journal of Vegetation Science* 1: 325 – 334.

Wickens, G.E. (1980). Alternative uses of browse species. In: *Browse in Africa. The Current State of Knowledge* (*Edited by Le Houreou, H.N.*). International Livestock Centre for Africa, Addis Ababa, Ethiopia. pp. 155 – 182.

Winks, L., Laing, A.R. and Strokoe, J. (1972). Level of urea for grazing yearling cattle during the dry season in tropical Queensland. Proceedings. *Australian Society of Animal Production* 9: 528 – 135.

Yahaya, M.S., J. Takahashi., S. Matsuoka., A. Kibon and D.D. Dibal. (2000). Evaluation of arid region browse species from north eastern Nigeria using pen fed goats. *Small Ruminant Research* 38: 83 – 86.

Yates, N.G and Panggabean, T. (1988). The performance of goats offered elephant grass (Pennisetum purpureu) with varied amounts of Leucaena leucocephala or concentrate. *Tropical Grasslands* 22(3): 126 – 131.

Zeeman, P.J.L., Marais, P.G. and Coetsee, M.J. (1983). Nutrient selection by cattle, goats and sheep on natural Karoo pasture. Digestibility of organic matter. *South Africa Journal of Animal Science* 13: 236 – 239.

Zemmelink, G. (1990). Effect of Selective Consumption on Voluntary Intake and Digestibility of Tropical Forages. Agricultural Research Report 1986. Centre for Agricultural Publishing and Documentation Wangenigen. 167pp.

APPENDICES

Appendix 1: Chemical composition of the feedstuffs used in the study (as %DM)

Component	Feedstuffs			
	Hay	SSC	AT	HM
DM	86.21	90.40	86.88	87.62
OM	86.78	95.60	93.19	92.87
Ash	13.22	4.40	6.81	7.13
CP	11.36	23.92	26.44	12.01
NDF	75.15	46.53	39.03	22.00
IVDMD (%)	56.83	43.47	50.95	77.95
IVOMD (%)	57.91	46.14	51.16	78.41

SSC = Sunflower seed cake

AT = *Acacia tortilis*

HM = Hominy meal

Appendix 2: Chemical composition of the supplementary diets (as %DM)

Component	Supplementary diets (Treatments)			
	T_1	T_2	T_3	T_4
DM	90.49	89.39	88.90	87.40
OM	93.36	93.32	92.08	91.71
Ash	6.64	6.68	7.92	8.29
CP	17.58	17.01	16.49	16.52
NDF	49.53	39.09	41.12	40.28
ADF	32.79	29.51	32.41	30.12
IVDMD (%)	67.33	64.70	62.07	65.35
IVOMD (%)	68.22	66.93	65.44	66.94

Appendix 3: Individual initial, final, average weight and weight gain of weaner goats

Treatment	Initial wt	final wt av	Av-Wt	Wt-Ch(kg)	Gain(g/d)
1	11.76	12.33	11.70	1.79	19.67
1	10.91	12.46	11.83	1.57	17.25
1	9.28	10.29	9.50	1.02	11.21
1	8.91	10.64	9.61	1.73	19.01
1	9.29	11.74	10.59	2.45	26.92
1	7.54	9.71	8.59	2.18	23.96
2	11.26	13.81	12.43	2.48	27.25
2	10.53	12.48	11.79	1.89	20.77
2	10.82	13.39	11.90	2.56	28.13
2	10.56	14.44	12.52	3.94	43.30
2	8.6	10.24	9.44	1.64	18.02
2	7.9	9.9	8.77	2.02	22.20
3	11.7	14.56	13.06	2.82	30.99
3	9.14	11.51	10.35	2.34	25.71
3	8.73	11.57	10.09	2.79	30.66
3	9.75	13.5	11.58	3.77	41.43
3	6.82	10.26	8.50	3.42	37.58
3	11.35	13.57	12.33	2.23	24.51
4	10.21	12.75	11.49	2.55	28.02
4	9.51	12.33	10.94	2.83	31.10
4	10.9	14.82	12.96	3.84	42.20
4	8.53	10.79	9.59	2.31	25.38
4	12.37	16.03	14.22	3.63	39.89
4	6.73	8.98	8.07	2.25	24.73

Appendix 4: Individual goat's average daily feed intake (g/day)

Treatment	HDMI	CDMI	TDMI	DMI as %BW	DMI/W$^{.75}$	HCPI	C-CPI	TCPI	CPI/W$^{.75}$	HMEI	CMEI	TMEI	MEI/W$^{.75}$
1	179.49	210.70	390.18	3.34	39.69	20.39	37.04	57.43	11.23	1.42	2.11	3.53	0.56
1	136.93	212.98	349.91	2.96	35.96	15.56	37.44	53.00	10.86	1.08	2.14	3.22	0.51
1	99.59	170.50	270.09	2.84	33.85	11.31	29.97	41.29	9.76	0.79	1.71	2.50	0.39
1	139.32	172.53	311.85	3.24	37.91	15.83	30.33	46.16	10.26	1.10	1.73	2.83	0.45
1	165.60	189.59	355.19	3.35	39.42	18.81	33.33	52.14	10.79	1.31	1.90	3.21	0.51
1	152.99	153.47	306.47	3.57	40.68	17.38	26.98	44.36	10.18	1.21	1.54	2.75	0.43
2	232.20	219.83	452.03	3.64	42.99	26.38	37.39	63.77	11.75	1.84	2.16	4.00	0.63
2	191.62	209.55	401.17	3.40	40.39	21.77	35.64	57.41	11.23	1.52	2.06	3.58	0.57
2	290.23	210.14	500.37	4.21	48.46	32.97	35.74	68.71	12.18	2.30	2.07	4.36	0.69
2	215.27	220.95	436.21	3.49	41.51	24.45	37.58	62.04	11.61	1.70	2.17	3.88	0.61
2	139.13	167.51	306.65	3.25	37.87	15.81	28.49	44.30	10.08	1.10	1.65	2.75	0.43
2	151.40	154.90	306.30	3.49	40.01	17.20	26.35	43.55	10.06	1.20	1.52	2.72	0.43
3	203.35	229.67	433.02	3.32	40.03	23.10	37.87	60.97	11.54	1.61	2.18	3.79	0.60
3	217.10	182.21	399.31	3.86	44.35	24.66	30.05	54.71	11.06	1.72	1.73	3.45	0.54
3	237.27	177.39	414.65	4.11	46.75	26.95	29.25	56.20	11.23	1.88	1.68	3.56	0.56
3	233.14	202.69	435.83	3.76	43.92	26.48	33.42	59.91	11.45	1.84	1.92	3.77	0.60
3	181.97	148.12	330.09	3.88	43.80	20.67	24.42	45.10	10.28	1.44	1.41	2.84	0.45
3	197.35	217.08	414.43	3.36	40.20	22.42	35.80	58.22	11.30	1.56	2.06	3.62	0.57
4	215.38	198.70	414.08	3.60	42.27	24.47	32.82	57.29	11.23	1.70	1.92	3.62	0.57
4	246.99	188.93	435.92	3.98	45.86	28.06	31.21	59.27	11.43	1.95	1.83	3.78	0.60
4	261.90	223.57	485.47	3.75	44.30	29.75	36.93	66.69	11.98	2.07	2.16	4.23	0.67
4	226.86	165.37	392.23	4.09	46.36	25.77	27.32	53.09	10.99	1.79	1.60	3.39	0.54
4	293.45	245.71	539.16	3.79	45.23	33.34	40.59	73.93	12.52	2.32	2.37	4.70	0.74
4	174.58	139.36	313.94	3.89	43.67	19.83	23.02	42.85	10.10	1.38	1.35	2.73	0.43

HDMI = hay DMI, CDMI = concentrate DMI, TDMI = total DMI, DMI as %BW = DMI as percent body weight, DMI/W$^{.75}$ = DMI per kg metabolic weight, HCPI = hay CPI, C-CPI = concentrate CPI, TCPI = total CPI, CPI/W$^{.75}$ = CPI per kg metabolic weight, HMEI =hay MEI, CMEI = concentrate MEI, TMEI = total MEI, MEI/W$^{.75}$ = MEI per kg metabolic weight, DMI = dry matter intake (g), CPI = crude protein intake (g), MEI = metabolizable energy intake (MJ)

Appendix 5: Individual goat's digestibility coefficients of DM, CP and OM

Treatment	DMD	CPD	OMD
1	63.40	61.53	67.96
1	64.67	63.48	69.31
1	62.35	64.50	66.58
2	64.46	60.68	68.60
2	68.26	63.64	71.84
2	60.24	56.70	64.62
3	62.43	57.76	67.23
3	64.51	61.39	68.48
3	72.17	68.69	75.76
4	64.76	61.45	69.36
4	71.49	70.45	75.50
4	67.66	60.85	79.31

DMD = dry matter digestibility, CPD = crude protein digestibility, OMD = organic matter digestibility

Appendix 6: Individual goat's values for nitrogen utilization

HIN	CIN	TNI	TFN	TUN	TNO	NA	NR
3.42	8.59	12.01	4.91	6.74	11.65	6.95	0.35
6.17	8.87	15.03	5.81	7.77	13.58	8.95	1.45
2.16	7.49	9.65	2.89	5.87	8.85	6.57	0.80
7.48	8.76	16.24	6.39	8.15	14.54	9.52	1.70
5.38	7.30	12.69	4.61	5.62	10.23	7.83	2.46
3.68	7.08	10.77	4.30	5.85	10.14	6.30	0.62
4.76	8.94	13.70	5.27	7.63	12.90	8.22	0.80
2.27	7.69	9.97	2.95	5.32	8.26	6.92	1.70
4.18	7.07	11.25	4.41	5.79	10.19	6.66	1.06
5.79	8.71	14.49	5.57	7.99	13.56	8.67	0.93
4.45	9.42	13.87	5.07	5.14	10.20	8.60	3.67
4.84	10.69	15.54	5.33	6.30	11.64	9.99	3.90

NIH = Hay N Intake,CIN=Concentrate N Intake,T NI=Total N Intake, TFN=Total Faecal N, TUN =Total urinary N, TNO = Total nitrogen output,NR = Nitrogen Retention