EVALUATION OF PERFORMANCE OF GROWING DAIRY GOATS FED RHODES GRASS HAY, SUPPLEMENTED WITH DRIED CALLIANDRA LEAVES AND COMMON VETCH HAY

NGUNJIRI, VIRGINIAH WANJIKU

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EGERTON UNIVERSITY

OCTOBER, 2020

DECLARATION AND RECCOMENDATION

Declaration

I declare that the work presented in this thesis is my original work and has not been submitted or presented for examination for a degree in any other university, either in part or whole.

Signature…………………………………………… Date 3rd November 2020 ………………………

Ngunjiri, Virginiah Wanjiku

KM11/1951/07

Recommendation

This Thesis has been submitted with our recommendation and approval as the University supervisors.

Signature…… Date…4th November, 2020

Dr P. K. Migwi, PhD

Senior Lecturer,

Department of Animal Sciences,

Egerton University

Signature…… Date…4th November, 2020

Prof A. Y. Guliye, PhD

Associate Professor,

Department of Animal Sciences,

Egerton University

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DEDICATION

This thesis is dedicated to my parents, the late Samuel Ngunjiri and my dear mother Gladys Wangui for their tireless commitment towards my education and my lovely daughters Fiddy and Joyphine for their encouragement throughout the study period.

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ABSTRACT

A study was conducted to evaluate the performance of growing dairy goats in two experiments. Experiment one determined the effect of supplementing Rhodes grass hay with dried *Calliandra calothyrsus* leaves and common Vetch hay on voluntary feed intake, live weight gain and average daily gain of weaned dairy goats. Twelve (12) cross-bred (Toggenburg x Small East Africa goat) weaned male goats aged between three and four months were used. A randomized complete block design (RCBD) with four blocks based on live weight and three dietary treatments were used comprising of; T1: Rhodes grass hay alone (Basal diet) as the control, T2: 30% Calliandra + Basal diet, T3: 30% Vetch + Basal diet. The animals were confined in individual pens. Clean water and complete mineral lick were availed *ad libitum*. The initial 10 days were allowed for adaptation to the diets and then data collected for 8 weeks. The intake of both the basal and supplement for each animal was recorded daily. Each goat was weighed weekly and live weight recorded. The results indicate total DMI was significantly different ($P<0.05$) for the supplemented goats compared to those fed on the control, recording 290.44 g/d, 492.31 g and 527.25 g for T1,T2 and T3 respectively, but was not significantly different ($P>0.05$) for the supplemented goats (i.e. T2, T3). Un-supplemented goats lost weight (-1.09 Kg) and had a negative daily gain (-19.46 g/day). Though the goats in T2 had the highest TLWT gain (3.41 Kg) and ADG (60.9 g/day) followed by those in T3 (2.86 Kg TLWT; ADG 51.12g/day) the difference was not significant ($P>0.05$). Experiment two determined the effect of supplementing Rhodes grass hay with mixed diets of dried Calliandra leaves and common vetch hay on growing dairy goat's performance. The same goats in Experiment 1 were used but aged between six and seven months under a similar experimental design. The four dietary treatments were as follows: T1: Rhodes grass hay alone (control), T2: 30% supplement (75% Calliandra + 25% Vetch) + Basal diet, T3: 30% Supplement (50% Calliandra + 50% Vetch) + Basal diet and T4: 30% Supplement (25% Calliandra + 75% Vetch) + Basal diet. Goats in T3 had the highest total DM intake (816.5 g/day) compared to an intake of 424 g/day for those in T1. Supplementation significantly ($P<0.05$) increased the TLWT from 0.6 Kg to 5 kg, 4.3 Kg and 3.7 Kg for goats in T1, T2, T3 and T4 respectively. It was concluded that supplementing Rhodes grass hay with dried *Calliandra calothyrsus* leave and common vetch (*Vicia sativa*) hay on growing dairy goats improved voluntary feed intake, increased total live weight gain and average daily gain.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADF	Acid detergent fiber
ADL	Acid detergent Lignin
ARC	Agricultural Research Council
ASDS	Agriculture Sector Development Strategy
CP	Crude Protein
DCP	Digestible Crude Protein
DM	Dry Matter
DMI	Dry Matter Intake
GDP	Gross Domestic Product
HIV/ AIDS	Human-Immunodeficiency Virus Acquired Immune Deficiency Syndrome
IU	International Unit
KALRO	Kenya Agricultural and Livestock Research Organization
KJ	Kilo Joules
LSD	Least Significance Difference
LWT	Live Weight
$LWT^{0.75}$	Metabolic Body Weight
ME	Metabolizable Energy
MJ	Mega Joules
NDF	Neutral Detergent Fiber
NRC	National Research Council
PRFs	Protein-Rich Forages
SRA	Strategy for Revitalizing Agriculture

CHAPTER ONE

INTRODUCTION

1.1 Background information

The agricultural sector contributes about 30% of the gross domestic product annually and another 27 % indirectly. It accounts for 65 % of Kenya's total exports earnings and provides 18 % of formal employment and more than 70 % of informal employment in the rural areas (ASDS, 2010). Agriculture remains the backbone of Kenya's economy and the means of livelihood for most of the rural population where close to 70% of Kenyans live in rural areas (Musyoki, 2017). Over 18 million Kenyans earn income from Agriculture (ASTGS, 2019). It is also estimated that about 50% of the population live below poverty line with the highest poverty indices being found in the rural areas, especially in the arid and semi-arid lands (Musyoki, 2017; SRA, 2004).

The sector's development strategy is geared towards ensuring 100% national food and nutritional security for all Kenyans, generating higher incomes as well as employment, especially in the rural areas. Although much has been achieved to this end, the challenges of food security, poverty reduction and transforming agriculture from subsistence to farming as a business still remains (ASTGS, 2019). Major challenges facing the agriculture sector include among others: effect of climate change which has been felt mostly by farmers, especially due to dependence on rain-fed agriculture, the high cost of key farm inputs, pests and diseases, and increased land sub-division to uneconomically small units (Kibet, 2011). The land and population pressure is one of the principal barrier to agricultural productivity where the average farm size has been decreasing while land distribution is becoming more concentrated leading to significant constraints on production, particularly for smallholders. Most farms range from 0.2 to 3.0 Ha (Birch, 2018). However, despite these challenges, the current Agriculture Sector Development Strategy (ASDS) aims to strategically make the agriculture sector a key driver for achieving the 10 percent annual economic growth rate expected under the economic pillar of Kenya's vision 2030 (ASDS, 2010; KARI, 2012).

The livestock industry plays an important role in; food and nutrition security, employment creation and income generation through sale of livestock and livestock products, especially for rural communities in Kenya. It is reported that 60-80 % of rural households keep livestock to supplement their food needs and incomes (Asseya & Mbugua, 2019). The livestock sector contributes 12 % of the national gross domestic product (GDP), 40 % of the agricultural gross domestic product and about 50 % of the agricultural labour (Macmillan, 2019). In the arid and semi-arid lands (ASALs) of Kenya, the livestock sector provides livelihoods for more than 95 percent of families and employs 10 million people along the supply chain (Taylor *et al*., 2014).

Small ruminants are critical to the development of sustainable and environmentally sound production systems. Sheep and goats contribute about 30% of the total red meat consumed in Kenya, and about 17% of the total milk production (ICPALD, 2013), thus significantly contributing to the food and nutritional security and well-being of many Kenyans. The nutritional and medicinal benefits of goat milk has led to increased demand of goat milk by people of all income levels unlike the traditional belief that goats have for a long time been referred to as the "poor man's cow" (Haenlein, 2004).

In spite of its enormous potential, the dairy goat industry is faced with major challenges that include among others; inadequate nutrition, poor quality breeds, shortage of quality breeding and replacement stock and inappropriate management resulting to an overall low performance which is often below optimum levels (Rangoma, 2013). Among these factors; nutritional constraint is the most critical (Nsahlai *et al*., 2000). There are also limited inputs allotted to goat production by the farmers as illustrated by lack of adequate animal health care and little supplementary feeding compared to other agricultural activities like cropping (Mburu *et al*., 2014).

Effort should be intensified to improve productive and reproductive performance of these animals using simple and cost-effective options. Desertification, drought and global warming justify the needs for a serious reflection on the readjustment and or the establishment of new feeding strategies targeting the improvement of animal production without detrimental effects on the environment (Salem, 2010). Therefore, the development objectives should move towards resource conservation and natural resource management, while striving for greater agricultural production. A wide range of local and alternative feed resources and secondary compound-containing plants and their extracts could, if adequately used, improve sheep and goat health, performances and the quality of their products (Salem, 2010).

The most common practice by most of the small scale dairy goat farmers in mitigating this challenge is by growing and feeding goats with mixed diets from various forages without scientific information on their performance (SoftKenya, 2014). In addition, Kimoro (2002) recommended investigation of the combinations of various browse plants in a study done to evaluate the potential of four browse plants to growing cross-bred weaned goats fed a poor quality basal diet of maize stover as opposed to sole protein sources after the study showed differences in efficiency of protein utilization among *Leucaena leucocephala*, *Albizia lebbeck*, *Gliricidia sepium* and *Moringa oleifera* leaf meals. However, research and development efforts that can significantly improve productivity from goats have received less attention. Compared to sheep, fewer management (mainly nutrition) and production related research projects have been undertaken with goats (Solomon *et al*., 2014). Thus, there is a compelling reason for goat research and development to get more investment and attention in the development agenda of developing countries (Solomon *et al*., 2014).

The objective of the present study was therefore to evaluate the performance of growing dairy goats fed Rhodes grass hay as the basal diet and supplemented with dried Calliandra (*Calliandra calothyrsus*) leaves and common Vetch (*Vicia sativa*) hay.

1.2 Statement of the Problem

Proper livestock feeding is a key factor influencing animal performance in terms of production and reproduction. Feeding of browses as supplements to low quality basal forages is commonly practiced by small scale livestock farmers in tropical areas. A recent approach like the FARM AFRICA MODEL advocated for the use of grown fodder legumes like the browse and fodder trees as protein supplements. Among the protein rich forages (PRFs), *Calliandra calothyrsus* and the common Vetch have gained popularity in dairy goat feeding in recent years as they are easy to grow and manage. However, despite their common use by farmers, not much has been done to evaluate effects on the performance of goats. In addition, most of the past research work undertaken on the use of fodder trees like *Leuceana leucocephala*, *Gliricidia sepium*, *Calliandra calothyrsus* as supplements in ruminant nutrition has mainly used either sheep or cattle. Therefore, there is inadequate information on the performance of dairy goats fed on most of these grown protein-rich forages.

1.3 Objectives

1.3.1 Broad objective

The overall objective was to contribute to information and knowledge on the performance of growing dairy goats fed Rhodes grass hay basal diet and supplemented with dried Calliandra (*Calliandra calothyrsus*) leaves and common Vetch (*Vicia sativa*) hay.

1.3.2 Specific objectives

i. To determine the effect of supplementary feeding of weaned dairy goats fed on Rhodes grass hay basal diet with dried Calliandra leaves and common vetch hay on voluntary feed intake and live weight gain.

ii. To determine the effect of supplementary feeding of growing dairy goats fed on Rhodes grass hay basal diet with mixed diets of dried Calliandra leaves and common vetch hay on voluntary feed intake and live weight gain.

1.4 Hypotheses

The following null (Ho) hypotheses were postulated for this study:

i. The supplementary feeding of weaned dairy goats fed on Rhodes grass hay basal diet with dried Calliandra leaves and common vetch hay has no effect on voluntary feed intake and live weight gain.

ii. The supplementary feeding of growing dairy goats fed on Rhodes grass hay basal diet with mixed diets of dried Calliandra leaves and common vetch hay has no effect on voluntary feed intake and live weight gain.

1.5 Justification

The latest national census carried out in August, 2019 showed that Kenya's population has increased to 47.6 million people from 38.6 million people in 2010 and is projected to grow to 99 million people by 2050 (KNBS, 2019). This growing population coupled with higher household income level will continue to increase the overall demand for food in terms of quality and quantity, especially protein rich food such as milk and meat. Consequently, the demand for animal products will continue to increase. This scenario calls for attention to ensure that the rising population is generally food and nutritional secure and generation of more farm incomes thereby contributing to poverty reduction. The demand for milk in developing countries is expected to increase by 25% by 2025 (Delgado *et al*., 1999) and quadruple during the year 2030 to 2050 (Assefa & Mbugua, 2019). It is therefore becoming increasingly important to maximize agricultural production through improved crop and livestock management practices and ensure adequate supply of quality livestock feeds throughout the year. Goyal and Mash, (2017) recommended the need to support agricultural research and development in order to generate knowledge to ensure increased productivity.

Supplementation of ruminants is a strategy which has been reported to be economically sustainable and applicable, especially when ruminants are fed conventional low-quality roughages such as poor quality grass and crop residues (Bohnert *et al*., 2000). Past research has recommended the use of grown protein-rich forages (PRFs) to mitigate this challenge in nutrition (Tsutomu *et al*., 2003). Most researchers have indicated the need for continued research on PRFs that include shrubs/fodder trees and other herbaceous legumes in order to diversify the animal feed resource base to enhance animal nutrition (Wilkins, 2000). The present study aimed at supplementing Rhodes grass hay with dried Calliandra (*Calliandra calothyrsus* leaves and the Common Vetch (*Vicia sativa*) hay to contribute to existing knowledge. The information obtained may be used by goat producers, other researchers, animal nutritionists and any other interested stakeholder involved in dairy goat development.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of the Dairy goat industry in Kenya

The improvement of the dairy goat industry in Kenya started as early as 1950's with the introduction of exotic dairy breeds by the white settlers which include Saanen, Toggenburg, Alpine and the Anglo-Nubian. The exotic breeds have been used to cross with the local goats to get a better adapted and higher yielding goats than the local goat (FAO, 2010). Commercial dairy goat farming under intensive or semi-intensive system has been growing quickly and contributing much to income, economic growth and better human nutrition (Reddy, 2018). Majority of smallholder dairy goat farmers in Kenya rear the improved dairy goats. The dairy goat population has been increasing over time (Figure 2.1). A total of 502,044 dairy goats were reported in 2017 up from 178,000 in 2007 showing an increase of 181% over the ten-year period (MoALF, 2018). This signifies the popularity of the dairy goats in Kenya. Most of these goats are found in the high potential areas of the Kenya highlands in the central, Rift valley and Eastern regions.

The popularity of the Toggenburg x local goat crosses has spread within East Africa with several buyers from different countries purchasing the cross-bred goats from Meru Dairy Goat Breeders Association (MGBA), in Eastern Kenya. The MGBA has proved that Toggenburg goats and their crosses have become income generators where a registered cross-bred goat is offered at US $ 154 and prices up to US $ 450 for pure breed (Bernardine, 2011). An increase in milk production from local goats has been reported from an average of 0.25L per goat per day to 1.0 –4.2 L/doe per day for the improved goats (Bernardine, 2011; Mburu *et al.,* 2014).

The contribution to the livelihoods of rural households by small ruminants has also been reported in other developing countries (Haenlein, 2004; Peacock, 2005; Pakistan, 2013). For example, in Zimbabwe goats contribute between 11 and 15% of the income obtained by low income farmers in a year (Kusina *et al*., 1998), while the experience of Farm-Africa in Ethiopia reported improved rural livelihoods (Gebremeskel, 2000). Sheep and goats are regularly slaughtered for social and religious occasions and also sold for household incomes. There is substantial potential for higher returns from small ruminant production with minimum increase in resource allocation based on the increasing demand for their products, relatively lower cost of production compared to cattle and the ability of small ruminants to effectively utilise poor quality forage (Pakistan, 2013).

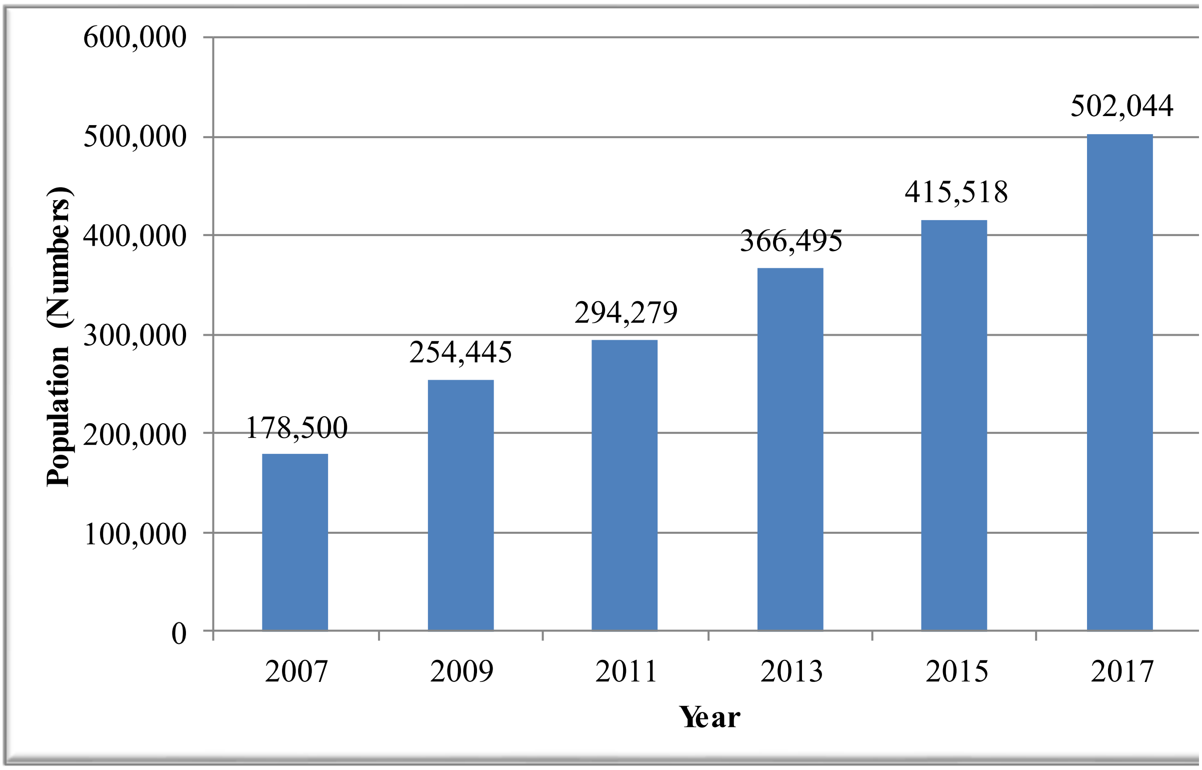

Figure 2.1: Dairy Goat Population trend in Kenya. Source: MoALF (2018).

2.2. Role of Dairy goats in food production and poverty reduction

Milk production is the major objective of keeping dairy goats though there are also other objectives such as production of breeding stock for sale and manure production. Out the total milk produced in Kenya, cattle account for 88 % while the rest comes from camels and goats (RoK, 2013). Investing in goats is a sure way of getting higher returns after a short period of time since the chances of getting multiple births is higher in goats compared to cows if well managed (Bizna, 2018). Goats are therefore an important source of food and income to many rural households. The contribution to food security and poverty alleviation is both directly through family consumption of milk and meat and indirectly through income generation from sale of goat milk and sale of replacement and breeding stock. A success story shared by Shamba Dairies in Murang'a whose goats produce 2.5 to 3 liters of milk per goat per day where the farmer makes Ksh 80,000.00 per month from sale of goat milk products and fresh goat milk (#FarmersTrend, 2016; Bizna, 2018). The upgraded local X German Alpine in the dry areas of Central Kenya produced 1.5-2.5 L per doe per day (CKDAP, 2006). In Tanzania, milk yield of 1.07-1.4 Kg/doe/day from improved dairy goats has been reported (Nordhagen, 2003). The performance of the dairy goats and their crosses has varying degree of success depending on environment and the level of management. The dairy goats, therefore, have more potential for high milk production when adequately fed and properly managed.

The importance of dairy goat farming cannot be overemphasized. Farmers keeping improved and pure dairy goats can gain more than twice higher returns in terms of milk production and sales than those keeping local goats (Ingratubun *et al*., 2000; Bernadine, 2011). Annual off-take under improved management can be as high as 60 % and are known to have higher twinning rate of 43.8% than 26.2% in sheep with most research report that goats can attain a twinning rate of 19 to over 70% (Akinlawon, 2003). Achariya (2009) reported a twinning rate of 54% for Beetal goats, 19 to 50% for Jamunapari, and 47 to 70% for Barbari goats while a twinning rate of 50% or more for Tswana goats and 50% in a sub-agro-ecological zone in Ethiopia was reported (Tibbo, 2000; Monkhei & Madibela, 2005). Although twinning is a genetic factor, incidences of twinning vary with breed, environment and the number of kidding. Litter size is a phenotype, which is greatly influenced by nutrition (Carles, 2008). Monkhei and Madibela (2005) concluded that supplementary feeding when practiced improves weaning weight of supplemented kids to 14.1 Kg compared to 12.3 Kg of the un-supplemented kids and while practiced on twin bearing does, gross margin improved greatly, indicating that multiple births contribute positively to profitability of goats. Non-marketed benefits like manure production raise returns to the crop production systems and are known to contribute to additional revenues for the livelihoods of rural households (Staal *et al*., 2003).

It has been noted that decline in land sizes with each generation inheriting land, further decreases available household production option especially, in the high rainfall areas (Birch, 2018). The alternative use of dairy goats under more intensive system of production has been viewed as a viable option. The potential of the dairy and dual-purpose goats in Kenya has been recognized since the early 1980's (Siamba *et al*., 2005) and remain high even today (Homann *et al*., 2007; Mburu *et al*., 2014). Currently, there is insatiable demand for both pure and improved dairy goat (crosses) breeds hence there is an urgent need for a significant scaling up of the current goat development activities to meet this rising demand (Peacock, 2008; Reddy, 2018). The improved dairy goats contribute to food security and improved livelihoods, especially for the resource poor households, particularly in the more densely populated areas (Mosomo *et al*., 2012; FarmersTrend, 2016; Bizna, 2018).

2.3. Importance of Goat milk in human nutrition and health

Goat milk is known to have both nutritional and medicinal benefits (Haenlein, 2004). It is becoming more and more popular worldwide by people with lactose intolerance conditions and is more easily digested (FAO, 2010) and those with allergic reaction to cow's milk.

The critical question for all those trying to establish a dairy goat business is 'why goat milk' when there is relatively easier and cheaper access to cow's milk? Recent studies have shown that goats' milk and its products like yoghurt, milk powder, and cheese can contribute significantly to the human nutrition. Apart from feeding the starving and malnourished people, goat milk can be used to treat people affected by cow milk allergy and other gastrointestinal tract disorders (Haenlein, 2004; Axe, 2018). Goat milk is known to have superior nutritive and health attributes compared to cows' milk (Edward, 2018).

The high levels of short and medium chain fatty acids in goat milk is associated with its medicinal value and can be used in treating many disorders and human diseases. The medium chain fatty acids (MCFA that include caproic (C6:0), caprylic (C8:0) and capric acid (C10:0) are established treatment for a variety of malabsorption syndrome cases of patients suffering from steatorrhea, hyper-lipoproteinemia, intestinal resection, premature-infant feeding, cystic fibrosis and gallstones (Getaneh *et al.*, 2016). They have also been reported to lower blood serum cholesterol level, inhibiting and limiting cholesterol deposition in soft tissues and correcting unthriftness in growing children (Getaneh *et al.*, 2016). Cow milk allergy is considered a common phenomenon and treatment with goat milk can resolve between 30-40% of the allergies related to cow's milk especially, those related to lacto-albumins (Haenlein, 2004). Researchers suggested that goat milk should be consumed regularly by individuals with mal absorption conditions, anemia, osteoporosis or prolonged treatment with iron supplements since it is reported to boost regeneration of hemoglobin (Axe, 2018).

The per capita milk consumption in Kenya is currently the highest in the Sub-Saharan Africa estimated at 121 L per person per year (Kurt, 2019; Macmillan, 2019), against 25 L per capita for Sub-Saharan Africa. This is still below the global recommendation by the world Health Organization of 220 L per capita (SDP, 2004; Steinfield *et al*., 2006; ChartsBin, 2011; RoK, 2013; Sandra, 2013; Kurt, 2019). One uncontested fact in Africa, including Kenya, is that the demand for milk is growing across the continent which is normally driven by human population growth and the increasing per capita milk consumption (Kurt, 2019). Tetra Pak is projecting Africa milk demand to increase by more than 50 percent in liquid milk consumption, growing from 15 billion L in 2010 to almost 25 billion L in 2020 (Kurt, 2019).

2.4. Goat feeding

Proper goat feeding is a major environmental factor that influences animal production performance. Small ruminants like all other animals need to be provided with proper amounts of all the nutrients necessary for optimum production (Wahlberg & Scott, 2006). The major nutrients required include: water, carbohydrates, proteins, fats, a range of vitamins and minerals. Provision of proper housing and general care for the goats would lead to proper growth and development, maximize production potential and profit (Mdukatshani, 2015).

Despite their similarity with other ruminants, goats exhibit significant differences from cattle and sheep in grazing habits, dietary selection and water requirements. Goats are mainly browsers and have unique aspects in dietary selection where they prefer fresh and dry leaves, flowers, fruits, pods and tender shoots of shrubs which are of higher nutritional quality (Pfisher *et al.,* 1988; Mdukatshani, 2015). By means of their mobile upper lip and very prehensile tongue, goats are able to feed on very short grass, and to browse on foliage not normally eaten by other ruminants. Goats also have a competitive advantage over other ruminants due to their bipedal stance which enable them to stand on their hind legs, climb rock cliffs, and low growing trees to gain access to relished plants and plant parts that are unavailable to other livestock species. Helena, 2010 reported that goats browse more than sheep or cattle and spend about 4% of their grazing time in a bipedal stance.

Dairy goats can feed on a wide range of feeds including grasses, protein-rich forages (PRFs) and home-made rations (Tanmay, 2014). The use of multipurpose trees and other fodder legumes has gained popularity as the cost effective source of protein in animal nutrition (Wambui *et al*., 2006). Feeding adequate and good quality forages to dairy goats at the farm level would therefore be a cheaper option of increasing milk production, growth rates and getting replacement stock, which reduces both production and replacement costs (Agbabiaka, 2019). The integration with the cropping system not only improves animal performance, but also improves soil fertility since some PRFs are nitrogen-fixing and the application of goat manure on the soils results in high potential of increasing crop yields consistent with greater economic returns. Among the most common protein-rich forages (PRFs) used in dairy goat feeding include: *Calliadra spp*, *Leucaena spp*, *Sesbania spp*, *Medicago spp* (*Lucerne) Desmodium spp* and sweet potato vines. Vetches which are potentially adapted to most areas of the Kenyan highlands has gained popularity in the recent times particularly in Central, Eastern and Rift Valley regions in Kenya (Rangoma, 2018). A noted success is the goat model which was promoted by FARM-AFRICA, the Central Kenya Dry Areas Project, the Dairy Goat Association of Kenya (DGAK) and the Meru Dairy Goat Breeders Association (MDGBA) (Bernardine, 2011) for improving productivity and economic returns of goats. One of the key areas is the way in which farmers improve the feeding of goats using local feed resources as well as growing protein-rich forages. There is also recommended development of various feeding systems that utilize optimum levels of legume tree leaves and bran as supplement with straw and tropical grasses for ruminant feed (Tsutomu *et al*., 2003).

Cultivated forages and use of various crop residues, kitchen wastes such as potato and banana peels are common in feeding the dairy goats (FAO, 2010). In most cases, dairy goat farmers use more than one type of forage at any one feeding time; hence the use of mixed rations is quite common (FAO, 2010; Wambui, 2017) despite lack of nutritional information on the used diets.

The primary objective of a good goat management programme is for a doe to reach 45 Kg live weight at first kidding which translates to a growth rate of about 120 g/day for the exotic breeds and 20-35 Kg live weight for the local goats (Luo *et al*., 2004a; Carles, 2008). Some studies indicated a mean body weight gain of 139 g/day and a maximum gain of 272 g/day (Luo *et al*., 2004a). However, lower pre-weaning growth rate of 92 g/day and a post-weaning growth rate of 76 g/day and growth rate range from 50-100 g/day for kids aged between 1-3 months which then drops to between 30-75 g/day at 3-12 months for exotic and local goats, respectively, has been reported (Luo *et al*., 2004a). Supplementation for growing goats is not commonly practiced due to the high cost of commercial feeds. The low growth rate of these improved dairy goats leads to late attainment of puberty and sexual maturity, consequently delayed age at first kidding. Since goats reach sexual maturity as early as 4-6 months, early breeding which has been practiced enable females to kid as yearlings (365 days). Safaa *et al*. (2015) reported age at first kidding for Saanen goats at 458.11 ±11.89 days.

Therefore, in order for goats to grow well, it is necessary to develop a year round forage programme allowing for enough feed throughout the year. However, one of the key challenge in smallholder dairy production include high costs and inaccessibility of dairy production inputs like commercial feeds and other support services (Muia *et al*., 2011). But even though pastures and fodders are reported to be the cheapest form of animal feeds available in terms of quality and quantity and therefore recommended for ruminant feeding (Bakhashwain, 2010), inadequate nutrition is still one of the major constraints in goat feeding (Muia *et al*., 2011). The deficiencies can partly be mitigated by supplementing roughage diets with commercial feeds containing the deficient nutrients through supplementation. However, the use of such commercial feeds to supplement goat diets is highly constrained by high cost (Muia *et al*., 2011).

2.4.1 Nutrient requirements of goats

2.4.1.1 Energy and protein requirements in goats

Dairy goats need sufficient energy in their diet to allow them to grow, reproduce and produce milk. Carbohydrates have the primary function in providing energy to animals and goats are of no exemption. The energy requirement for maintenance is necessary for supporting body functions, normal activities and thermoregulation. Databases obtained from different publications to determine Metabolizable energy for maintenance (ME_m) and body weight gain (ME_g) by regressing Metabolizable energy (ME) intake against average daily gain (ADG) was 485, 489, 580, 489 and 462 KJ/Kg $BW^{0.75}$ for ME_m and of 13.4, 23.1, 23.1, 19.8 and 28.5 KJ/g ADG for ME_g for the pre-weaning, growing meat, growing dairy, growing indigenous and mature goats respectively (Luo *et al.*, 2004a). The ME_m compare favourably with ME_m of goats recommended by NRC (1981) of 424.2 KJ/Kg $LWT^{0.75}$ and

ME_g of 30.3 KJ/g ADG. Medeiros *et al.* (2014) reported ME_m of 417 KJ/Kg $LWT^{0.75}$ and net energy for growth (NE_g) of 7.38-9.0 MJ/Kg of empty weight gain per day at 5 and 20 Kg body weight respectively for Saanen male goats. Nizar *et al.* (2014) reported higher ME_m of 542.64 KJ/Kg $BW^{0.75}$ and a corresponding requirement for 1 g gain of 24.3 KJ ME for growing sheep and goats in warm areas.

Protein is made up of amino acids which is the principal constituent of the animal body that is needed for growth of new tissues, repair and in vital metabolic processes. The protein also forms a major component of blood, anti-bodies, muscle and milk and is therefore required to produce these products. Normally, dietary crude protein (CP) requirement for growing goats tend to vary with breed, feed type and the growth phase (Negesse *et al.,* 2001). Past studies have recommended dietary CP of 15-18 % for growing goats to promote growth performance (Reddy, 2017; Park *et al*., 2018). The recommended CP requirement for maintenance for growing goat kid weighing on average 9 Kg live weight and growing at an average ADG ranging from 27 to 100 g/d required a CP of 10.7-17.2% (NRC, 2007).

The metabolizable protein requirement for maintenance (MP_m) was 3.07 g/Kg $BW^{0.75}$ for all biotypes of growing goats and metabolizable protein for body weight gain (MP_g) was 0.29 g/Kg per ADG for dairy and indigenous goats (Luo *et al*., 2004b). Digestible CP requirement was found to be higher for sheep than goats of 3.36 g/Kg $LW^{0.75}$ and 2.38 g/Kg $LW^{0.75}$ respectively (Nizar *et al.,* 2014). Abbeddou *et al*. (2011) reported the increasing levels of CP content in feeds improved CP intake and also enhanced CP digestibility which promotes growth performance of goats. Ki *et al*. (2009) found that high CP and energy were better than low CP and energy in feeds for higher intake, digestibility, and nitrogen and energy utilization in growing goats.

2.4.1.2 Mineral and vitamin requirements in goats

Minerals and vitamins are vital to the good health of goats since they are an integral part of proper nutrition (Gasparotto, 2015). In comparison to energy and protein, minerals are needed in relatively smaller quantities (macro and micro). The essential macro minerals are required at 0.1% or more in the diet which include calcium (Ca), phosphorus (P), magnesium (Mg), Sulphur (S), sodium (Na), potassium (K) and chloride (Cl) (Spencer, 2019). Essential micro minerals required in parts per million include: Cobalt, copper, molybdenum, fluorine, iodine, iron, manganese, selenium and zinc. The primary sources of these minerals are; diet, mineral supplements (loose and block), and, in some areas, the water supply (Spencer, 2019).

Growing goat kids weighing about 9 Kg LW at an ADG range of 27-100 g/d need 1.5-2.0 g calcium (Ca), 0.7-1.0 g phosphorous (P), 209-345 mg magnesium (Mg) and 7-9 mg copper (Cu) (NRC, 2007). In a study conducted to in-kid goats, daily Ca, P, Mg for maintenance were 60.4, 31,1 and 2.42 mg/Kg live weight respectively (Harter *et al*., 2017). Na in Saanen goats was 11.8 mg/Kg while K requirements increased as pregnancy progressed from 8.73 to 15.4 mg/Kg live weight (Harter *et al*., 2017).

Vitamins function as critical chemicals in the body's metabolic machinery and function as cofactors in many metabolic processes. Vitamins are divided into those that are fat soluble (Vitamin A, D, E and K) and those that are water soluble (B vitamins and C). The bacteria in the rumen of the goat can synthesize adequate amounts of the water soluble vitamins. Therefore, their deficiency is not a common occurrence for goats fed on forages. Fat-soluble vitamins must be supplied to the goat because the body cannot directly synthesize them. Vitamin D is synthesized from exposure to sunshine (Wahlberg & Scott, 2006). However, goats and sheep housed indoors for more than 2 to 4 weeks, Vitamin D should be included in the diet to avoid Vitamin D deficiency as may be seen as enlarged joints and bowed legs (rickets) (Gasparotto, 2015).

Growing goat kids weighing 10-20.5 Kg BW need 400 IU and 84 IU for vitamin A and vitamin E respectively, while those weighing 20.5 Kg 700 IU of vitamin A and 144 IU of vitamin E per day (NRC, 2007). A deficiency of a vitamin will slow or block the metabolic process in which that vitamin is involved, resulting in deficiency symptoms reflected in depressed growth rate, lowered resistance against infections and poor reproduction. Deficiencies or imbalances of key minerals and vitamins exert a significant effect on the health and productivity of goats which may reduce productivity, prolong duration of kidding, high number of still births and neo-natal deaths and higher occurrence of skeletal problems Therefore, goats need to be provided with proper minerals and vitamin supplements free choice.

2.4.1.3 Lipids/Fats and water requirements in goats

Lipids/fats are nutrients that provide energy thus increase the energy density of a feed without adding bulk. Generally, for cattle, goat, and sheep do not require much fat in their diet since ruminants get most of the energy from the pastures or forage provided. However, when there is a need to increase the energy in their diet, in most cases for the lactating or gestating animal, fat can be included in their diet but should not be more than 7% of the total diet (Abdulquadri, 2019), otherwise it will interfere with the fibrolytic activity in the rumen.

Water is the most frequently overlooked nutrient in a diet whereas it's the most important nutrient and both the amount and time of water intake closely relate to feed intake (Forbes, 2007; Dhia, 2012). Goats need an average of 4 liters of fresh, clean water per day (Esmail, 2018). The amount of water required by goats each day varies with many factors such as; ambient temperature, humidity, wind, activity level, whether growing or lactating. The goat's body is normally more than 60% water and rumen contents must be about 70% water to function properly (Gasparotto, 2015). It is a key factor in the digestion and absorption of nutrients such as carbohydrates, proteins, and fats. It also helps in excretion of body wastes after digestion and helps in the removal of some toxic metabolic products such as urea. Water intake also affects feed intake, ability to fight stress, illness and disease (Gasparotto, 2015). Lack. of water will, therefore, have more immediate and drastic effects on body physiology than the lack of other nutrients. Inadequate water intake or providing contaminated water also reduces feed intake. For these reasons, goats should have access to clean drinking water at all times without restriction (Forbes, 2007; Dhai, 2012; Gebreegziabher, 2016).

2.4.2. Leguminous forage as protein source for ruminant animals.

Leguminous forages are protein-rich forages (PRFs), which have the potential to improve quality of commonly fed grass-based diets in ruminant feeding. These include; herbaceous legumes like desmodium (*Desmodium spp*), Lucerne (*Medicago sativa*), vetches (*Vicia spp*); fodder trees and shrubs like Calliandra (*Calliandra spp*), Leucaena (*Leucaena spp*), Sesbania (*Sesbania spp*), Gliricidia (*Gliricidia spp*), and Mulberry (*Mulberry spp*). Sweet potato vines (*Ipomoea batatus*) is also considered a protein-rich forage. Legume forages contain high levels of CP typically in the range of 20-30% in contrast to local grass containing 8-10% in the wet season and less than 7% in the dry season (Wambugu *et al*., 2006).

Legume forages have multiple benefits that include improved rumen function, increased energy and protein intake, improved feed utilization efficiency and increased availability of minerals and vitamins with an overall enhanced animal performance (Kariuki, 1998). Fodder trees and shrubs have been and are still used as multipurpose resources providing food, valuable forage and browse, environmental protection, fuelwood, live fences across agro-ecological zones of the world (Ramana *et al*., 2000; Shelton, 2001; Wambugu *et al*., 2006). Past studies show that the type, form and quality of the browse have an effect on microbe-browse interaction and the digestibility of the diet (Darlis *et al*., 2000; Orden *et al*., 2000).

2.4.3. Utilization of *Calliandra Calothyrsus* and Common Vetch in supplementary feeding of goats

During supplementary feeding; animals should have access to sufficient basal diet, browse or hay or it will be ineffective to the animal. The supplement is supposed to supply the rumen microbes with the deficient nutrients to enable them digest the basal diet effectively.

Calliandra (*Calliandra calothyrsus*) is a common small thornless multipurpose tropical legume tree valued for its multipurpose attributes. It is used in agroforestry systems as a fodder for livestock feeding, fuelwood, fibre, honey, provides services such as shading, erosion control, weed control, soil improvement, and is also used as an ornamental plant (Orwa *et al*., 2009). Calliandra normally grows on all soil types and is well adapted to acidic soils of poor fertility. The use of fertilizer at later stages is still not necessary since it has an outstanding ability to grow in infertile soils due to its ability to fix nitrogen (FAO, 2016). It grows on a wide range of altitude from sea level up to an altitude of 1800-2200 M, but does better up to 1300 M. It grows best with annual rainfall of between 700 and 3000 mm, but will tolerate 4000 mm in the wet tropics. It likes annual temperatures ranging between 22 and 28°C, with the mean temperature of the hottest months being within 24-30°C and of the coldest months within 18-24°C (Heuze *et al.*, 2017).

Calliandra forage is a good source of protein having an average CP of 20.5% and can have a maximum of 28.2% CP (Tuwei *et al.*, 2003; Heuze *et al.*, 2017). It has a high dry matter (DM) yield of 7 – 20.0 ton /ha per year in a range of environments (Kabi & Bareeba, 2008). For maximum leaf production, it is recommended to be cut to a height of 0.5-1.0 M every 2-3 months. *Calliandra calothyrsus* can produce 15-40 tons of wood/ha per year under annual coppicing and remains productive for 10-20 years (Orwa *et al*., 2009).

Calliandra has been shown to have a beneficial effect on milk yield in improved dairy cows despite some of its apparent limitations like the high levels of condensed tannins of 25-30% of total DM and a relatively low digestibility of 35-40% (Tuwei *et al*., 2003). Some past studies have recorded improvement of DM intake and growth rate in goats when Calliandra leaf meal was used as a supplement (Kinuthia *et al*., 2007). In addition, regardless of the browse plant used, increasing graded levels (0 to 30%) of browse supplements resulted in linear increase in DM intake (Wambui *et al*., 2006). A past study reported that farmers feed Calliandra to a wide range of animals, 91% to dairy cows, 47 % to goats, and 42 % to heifers (Franzel *et al*., 2002). Work done by Paterson *et al.* (1999) in Embu research station has shown that 1Kg of Calliandra DM can replace 1Kg of dairy meal without affecting milk yield in dairy cow's suggesting that it has huge potential in other ruminants such as dairy goats.

Vicia (vetches) is a large genus of about 140 species of flowering plants in the family of *Fabaceae*, native to Europe, Asia and Africa (Bryant *et al.,* 2011). The common Vetch (*Vicia sativa*) is an annual scrambling and climbing legume (Plate 1). *Vicia sativa* provides palatable forage (fresh, hay and silage) and grain to livestock. It is found in areas with annual rainfall ranging from 310 mm to 1630 mm and on a large variety of soils, with a preference for well-drained, moderately fertile soils with a pH ranging from 6.0 to 7.0. (UC SAREP, 2006; FAO, 2010). *Vicia sativa* may be sown in pure stands or mixed with a cereal companion that helps it to climb. Vetches are adapted to a wide range of altitude including high altitude. They are also extensively grown as fodder and for hay, as a cover crop and also green manure. Weed suppression is increased when the legume is associated with a cereal companion crop (UC SAREP, 2006). At the flowering stage, vetch hay is a valuable forage with an OM digestibility of 64.4 - 69% and a CP content ranging from 12 to 24% DM (Haj Ayed *et al*., 2001; Henze *et al*., 2016). It produces a hay yield of 3.8-8.8 ton DM/ha from a biomass of 5.0-9.5 tons/ha (Rebole *et al*., 2004; FAO, 2010). At seed filling, the increased rumen bypass protein and lower ratio of "structural carbohydrates: non-fibre carbohydrates" indicates that *Vicia sativa* forage should be harvested at this stage (Caballero *et al*., 2001).

Plate 1: Common Vetch at dough stage (optimal harvesting stage)

Like other *Vicia* species, the seeds of *Vicia sativa* contain numerous anti-nutritional factors, notably cyanogenic amino acids and cyanogenic glycosides that are toxic to monogastric animals. Its use in pigs, poultry (the latter being the most sensitive) and humans is, therefore, restricted (Tate & Enneking, 2006). However, *Vicia sativa* forage normally does not contain anti-nutritional factors when it is grazed or cut frequently enough to prevent flowering and seed-heading. But some cases of poisoning of ruminants consuming common vetch forage have been reported with toxicity signs including severe dermatitis, skin oedema, conjunctivitis, corneal ulcers, and diarrhoea (Mayland *et al*., 2007).

2.4.4. Voluntary feed intake in goats and other ruminants

Feed intake is one of the most crucial factors for ruminants in terms of productivity and performance (Ocak *et al*., 2006; Gerbreegziabher, 2016). Voluntary feed intake (VFI) is the amount of feed eaten by an animal when the feed is provided without restriction. The knowledge of ruminant digestive system aids in understanding both the ecological niche and the feeding behavior of the ruminant animal. Factors controlling ruminant feed intake should be assumed to function with multiple interactions (Fisher, 2015). However, in some cases, the implicit assumption has been that each factor acted independently and exclusively of other mechanisms (Dwight, 2002). Pakistan (2013) reported that feed intake was significantly higher in goats than sheep and ruminating time significantly different between sheep and goats.

There are three main factors affecting feed intake that include: Animal associated factors, feed associated factors and environmental factors (McDonald *et al*., 1995; Gerbreegziabher, 2016).

2.4.4.1 Animal associated factors

The physiological status, age, body weight, and fatness, sex, genetic potential and health are the main animal associated factors that affect voluntary feed intake. The hunger hormone (Ghrelin hormone) mainly produced by the stomach stimulates appetite increasing feed intake and also promotes fat storage (Carline & Christine, 2007; Delporte, 2013). It plays a key role in regulating calorie intake and body fat levels (Klok *et al*., 2007)

The physiological status (dry, lactating, or pregnant) of an animal affect feed intake (Ocak *et al*., 2018). For example, a lactating animal has higher demand for energy than a dry one and a growing animal eats more feed per unit body weight than an adult animal (Dhia, 2012). Thus, high feed intake is expected in lactating or actively growing animals due to the active removal of digested material from the gut (Romney & Gill, 2000). An animal with higher production potential has higher physiological demand for nutrients thus increased voluntary feed intake, whereas loss of appetite due to diseases decreases voluntary feed intake. Growing animals only attain their growth rate in the presence of sufficient and high quality feeds (Forbes, 2007). Intake per unit of metabolic body weight tend to be high in lean animals than fat ones whereas young animals consume more feed per unit body weight than older animals (Dhia, 2012). Rumen volume determines the quantity of fermenting materials accommodated in the rumen at any one time. However, differences in rumen volume may occur within species due to variation in breed and age (Mgheni, 2000). The physical limitations caused by distension of the reticulo-rumen or other compartments of the gastro-intestinal tract often limit DMI of high producing cows or cows fed high forage diets (Michael, 2000). Heavily pregnant animals, especially, in the last trimester tend to have depressed intake due to the competition for the abdominal space by the gravid uterus (fetus) and the gastro intestinal tract (Rumen). The situation is exacerbated in does carrying multiple fetus. Hence the need for steaming up the pregnant animal to compensate for the reduced intake. Fermentation acids also limit DMI from a combination of increased osmolality in the reticulo-rumen and specific effects of blood circulating acetate and propionate, although the mechanisms are not clear. Males normally have higher feed intake due to the higher physiological energy demand than females (Dhia, 2012). Dominique (1989) reported that goats showed a superior utilization of low quality forage diet with a greater voluntary intake of dry matter (55.6 g/Kg W $^{0.75}$/day verses 38.8 g/Kg W $^{0.75}$/day) when compared to sheep. The greater voluntary intake for goats was associated with the larger rumen size of goats than sheep for the same body weight.

2.4.4.2 Feed associated factors

Nutritive value of a given feed highly correlates with its dry matter intake and its ability to supply the nutrients required by an animal for maintenance, growth and reproduction (Teferedegne, 2000). The feed chemical and physical characteristics, nutrient balances, the associative effects between dietary components and presence of anti-nutritive factors are major factors that affect feed intake in ruminants (Gebreegziabher, 2016). For grazing animals, the sward structure is also a factor the affect intake.

In grazing animals, availability and distribution of forage can have direct impact on short-term intake rate besides the quality of the diet (Garcia *et al.*, 2003). Grazing animals consume more in a pasture with short dense swards of digestible herbage whereas the availability and distribution of forage can have direct impact on short-term feed intake rate (Gebreegzizbher, 2016). The specific physical and chemical characteristics of diets that can affect DMI include: fiber content, ease of hydrolysis of starch and fiber, particle size, particle fragility, fermentation products, concentration and characteristics of fat, and the amount of ruminally degradable protein (Michael, 2000). The type and concentration of minerals also has a significant influence on intake both directly and indirectly. Feed palatability, deficiency of nutrients, physical form of feed, digestibility of feed, chemical composition of feed and the ratio of concentrate to roughage are additional factors which affect voluntary feed intake in ruminants (Dhia, 2012). The extensive interactions among the variables make it challenging to account for dietary effects when predicting DMI (Gebreegziabher, 2016). However, a greater understanding of the mechanisms along with evaluation of animal responses to diet changes allow diet adjustments to be made to optimize both DMI and allocation of diet ingredients to animals (Michael, 2000).

The palatability is determined by a multitude of factors such as sight, taste, odor, smell and absence of contaminants (Dhia, 2012). Some feeds are more palatable than others and for such feeds, an animal has a higher willingness to eat it. Nutrient imbalance is another very important factor that influence feed intake both directly and indirectly. Imbalance of nutrients can be felt at both rumen and at the tissue metabolism level. Nutrient imbalance reduces feed intake in animals since deficient nutrients reduces the activity of rumen microorganisms which affect feed digestibility and, therefore, reduce feed intake. The balance with regard to energy and protein is most important since deficiency of protein can greatly depress intake (Forbes, 2007) whereas excess protein consumed can be converted to energy (Fisher, 2002). Fibrolytic activity in the rumen can be depressed since rumen microbes are deprived key nutrients such as rumen degradable nitrogen and Sulphur. At the tissue metabolism level, metabolism of digestion products such as volatile fatty acids (VFAs) in body tissues can be depressed by nutrient imbalance. For example, lack of glucose can depress metabolism of acetate which accumulates in body tissues thus depressing further intake of dry matter. Similarly, deficiency of cobalt can depress feed intake through poor metabolism of propionate since its conversion to succinyl CoA requires Vitamin B_{12} as a co factor and cobalt is essential for the synthesis of Vitamin B_{12} by rumen microbes. The most common nutrient deficiency is protein or nitrogen deficiency which can be corrected through supplementation of rumen degradable protein and NPN. Other common deficient nutrients are: sulphur, phosphorous, sodium, cobalt, vitamin A, D and E.

Physical processing of roughage such as chopping, grinding or shredding of forages increases feed intake of low quality roughages due to increased rate of fermentation and passage (Bruinenberg *et al.,* 2002; Abu Bakar, 2018). Grinding and pelleting, though costly, increases intake. Feed preparatory methods that reduce dustiness usually results in increased feed intake such as moistening of feeds with water increases intake (Dhia, 2012). Generally, in ruminants, there are positive relationship between digestibility of feeds and their intake. In terms of chemical composition of feeds, the neutral detergent fibre (NDF) which in itself is the measure of cell wall content (CWC) are the main component which determines the rate of digestion (Patrick *et al.,* 2016). The higher the NDF, the lower the digestibility, and consequently the lower the feed intake (Riaz *et al.,* 2014). Forage that contains 40% NDF is generally of higher quality than that contains 60% NDF (Patrick *et al.,* 2016). Grass silage and hay have a wide range of NDF digestibility because grass species are so diverse and are utilized at extreme ranges in maturity. Feed intake could be limited when feed NDF is 100-120 g/Kg live weight (Valdes *et al*., 2000).

The presence of toxic substances in the feed like the alkaloids, glucosinolates, cyanogenic and condensed tannins contribute to depressed feed intake through different mechanisms (Romney & Gill, 2000). Leng (1997) indicated that tannin levels above 5% of the diet dry matter can be serious anti-nutritive factors in ruminants. However, in spite of the problems posed by secondary anti-nutritive compounds, beneficial aspects of the same has been reported (Leng, 1997). Nguyen *et al*. (2002) showed that low tannin levels of 0.29-0.74 % DM do not have any effect on nutritive value of diets. Condensed tannins at low levels have been associated with improved nutritive value by protecting proteins and some essential amino acids from excessive microbial degradation and thus making them by-pass proteins in the rumen to the small intestine (Jones *et al*., 2000). Dey *et al*. (2008) reported that feeding of condensed tannins containing diets particularly at 1.5 and 2% level significantly influenced N utilization and improved its retention. For some feeds, negative associative effect may occur during feeding. For example, concentrate supplementation may reduce roughage intake due to the inhibition of cellulose digestion by depressed population of cellulolytic bacteria due to lowered rumen pH, in cases where supplementation is done using a highly fermentable carbohydrate like sugar beet (Forbes, 2007).

2.4.4.3 Environmental associated factors

A number of environmental factors such as ambient temperatures, rainy and cold weather conditions, stresses and vices, housing, diseases and parasite infestations may affect feed intake in animals (Forbes, 2007; Dhai, 2012; Gebreegziabher, 2016).

Both high and low environmental temperatures affect intake in farm animals but through different mechanisms. Feed intake decreases in high ambient temperatures and increases at low temperatures relative to the animals' thermal neutral zones. Marai *et al.* (2007) reported that heat stress caused a decrease in feed intake, efficiency and utilization, disturbances in water and protein, energy and imbalances, enzymatic reactions, hormonal secretions and blood metabolites which impaired production and reproduction in sheep. Increased heat stress in animals lowers feed intake associated to effects that high temperatures has on feed intake, digestibility, microbial synthesis and passage rates (Mgheni, 2000; Forbes, 2007). High temperature in the environment increases heat load to the one already generated by microbial fermentation and metabolism of nutrients such as acetate, hence, the animal tends to reduce heat production by eating less. Obitsu *et al.* (2011), reported that the impact of high ambient temperatures caused a decrease in dry matter intake and milk yield in lactating dairy cows. In very cold climate, animals eat more to ingest adequate nutrients that generate more heat upon digestion and metabolism to keep the animal warm.

Grazing animals, especially, cattle and goats also reduce grazing time during heavy rain periods thus reducing feed intake. Housing of animals provides shade in hot climates resulting in increased feed intake due to the reduced impact of heat stress (Forbes, 2007). Poor health due to infectious diseases, gastrointestinal parasites such as ascarids, or metabolic disorders such as ketosis, lactic acidosis and bloat results to reduced feed intake (Dhia, 2012).

2.5 Factors affecting growth in goats

Several major changes occur as an animal passes from the zygote to its mature form and size. The most obvious change is in size and mass termed as growth. Growth and development are essentially ecological responses and it is thus appropriate to consider the factors affecting their outcome in an ecological framework. The main factors that affect the growth of small ruminants include: genotype, phenotype, sex, compensatory growth, nutrition, diseases, parity, body condition score and management, type of birth (single vs multiple births), litter size, season of birth and birth weight of the kid (Alade *et al*., 2008; Marete *et al.*, 2011).

The genetic traits comprise principally the hormones affecting growth that influences inherited performance potential the prospect animal has from parents at birth. This affects the growth potential, frame, size, muscle characteristics and maternal instincts. The effect of breeds was reported to be significantly different for growing goats. Weight of Red Sokoto goats at 9 months was 13.77±1.81 Kg, for Sahel goat was 13.49±2.07 Kg and for West Africa Dwarf goats was 8.63±1.42 Kg (Alade *et al*., 2008). Phenotypic weight of mature females from a representation sample of African environments range from 25-35 Kg for does (Carles, 2008). Growth rates for the same sample range from 75 - 140 g/day for lambs and 50-100 g/day for kids, from birth to 3 months of age. This drops to between 30-75 g/day for both species at 3-12 months. It is reported that male kids grow faster than female kids (Safaa *et al*., 2015). Males in semi-arid Nigeria at 9 months reached 12.64±1.88 Kg compared to females that attained 11.28±1.67 Kg. Zahrddeen (2008), reported higher ADG for males (92.94± 5.06 g) than females (84.16±6.58 g) of local goats in Nigeria. The major component of the maternal environment is the milk yield which has an effect on the level of milk intake available for the suckling kid and mothering ability, the natural instincts which help the doe to take care of the kid and thus greatly affecting the pre-weaning performance. This ultimately, also affects the kids post-weaning performance,

Compensatory growth occurs during a situation whereby the depression of growth due to some stress may be compensated in whole or in part when the stress factor is removed. Female goats less than one year of age of Nubian breed offered lowest dietary energy (8.5 MJ ME/Kcal) just maintained weight but after being subjected to higher dietary energy of 11.5 MJ ME/Kcal gained weight to reach final weight obtained by those goats which had no feed restriction (Yagoub & Salih, 2009). Supplemented West Africa Dwarf male kids reared on poor pastures gained 1.10 Kg live weight, while those not supplemented lost 1.48 Kg live weight (Anya *et al*., 2011). It was concluded that compensatory growth significantly affected daily and weekly rate of gain and total dry matter intake though the gain was lower in the compensating goats than the normally growing goats.

In single births, kids grow faster compared to multiple births (Alade *et al*., 2008). This can basically be explained by two factors; in single births, kids have higher birth weight than multiple births and the amount of milk available per kid. In multiple births, there is definitely higher competition with less milk being available per kid compared to the case in single births. Past reports showed that weight of 13.64±1.96 Kg and 12.33±1.66 Kg for single births and multiple births for goats at 9 months of age (Alade *et al.*, 2008). The average daily gain (ADG) was higher for single births (90.06± 4.03 g) and was 87.04±.58 g for twins (Zahrddeen, 2008). Kids born in higher parities are reported to gain higher weights than the first parity which can be explained by the fact that at higher parity, the doe is bigger in size thus dropping heavier kids and higher lactation yield. Good body condition of does result in higher postnatal kid weight and ADG. Zahrddeen (2008) reported that kids from a doe with a body score of 4 had the highest ADG of 91.61± 6.61 g and those with body score of 3 and 2 gained 89.37±5.37 g and 84.67±4.95 g respectively of local goats in Nigeria. Deribe and Taye (2013) concluded that goat kids from first parity does, twin born kids and those born during the dry season had lower growth rate than those of higher parity does, single births and those born during the rainy season. Generally, most researchers have concluded that management is a key factor responsible for most variation in livestock growth performance.

2.6. Challenges facing the Dairy goat industry in Kenya

The major challenges facing the dairy goat industry in many parts of Kenya includes; inadequate nutrition, health problems, high kid mortality, low genetic potential for milk production, inbreeding, traditional production system (Tibbo, 2000; Marete *et al.*, 2011). A study conducted in Mt Kenya region showed also that other challenges include; lack of market for goat milk and goats, high cost of concentrates, unreliable buck rotation programmes and insecurity in some parts (Mbinyo *et al.*, 2017).

In many parts of the tropics, animal productivity including that of goats is constrained by seasonal fluctuation in feed supply characterized by nutritional inadequacy during the dry season and drought. During such periods animals are mainly dependent on poor quality pastures and crop residues with little or no supplementation, leading to low animal production performance (Kariuki, 1998). For example, a crossbred Toggenburg or German Alpine goat which has a potential to produce 3 to 5 litres of milk per day per doe produces only 1 L/day/doe (Bernardine, 2011; Mburu *et al.,* (2014). A large proportion of animals kept by small scale farmers face periods when either they have too little or the feed they have to eat consists of unimproved natural pastures or crop residues (Tolera & Stanstøl 2000).

Generally, weight losses are also common, especially during the critical dry season (Solorio-Sanchez *et al*., 2000). The use of commercial feeds is not a viable option due to the high cost (Mbinyo *et al.*, 2017).

There is also evidence of inbreeding in goat production systems as demonstrated by the physical signs in some of the goats such as under developed udders and bisexual individuals (Marete *et al.*, 2011). High goat kid mortality has also been reported ranging from 13-50% (Safari *et al*., 2008). The high demand for improved dairy goats and shortage of breeding stock has led to higher prices of these goats making them less affordable by the resource poor small-scale farmers (MoLD, 2008). In a cross-sectional survey conducted in Mount Kenya region, the challenges of lack of market for goat milk and live goats ranked highest at 45%, diseases at 33%, high cost of concentrates at 25%, lack of feed at 19%, problems of unreliable buck rotation programme at 16.5%, while insecurity was least at 1.8% of the total samples by the dairy goat farmers (Mbinyo *et al.*, 2017).

2.7. Opportunities to improve the Dairy goat industry in Kenya

Genetic improvement of local goats through community-based goat breeding schemes through buck rotations and breeder's units if appropriately designed and adequately supported, would ensure continuous local supply of quality and locally adapted breeding stock in a sustainable way (Ahuya *et al.,* 2003; 2005). Strong and supportive policies also need to be put in place and implemented by the government as well as sound breeding plans (Kahi *et al*., 2005; Kosgey *et al.,* 2006). In addition, new software for buck rotation should be developed and put to use to avoid inbreeding (Marete *et al.*, 2011). Most research has recommended use of cross-breeding for improved growth rates and productivity (Mbuku *et al.*, 2015; Nirajan *et al.*, 2019).

More emphasizes on nutrition is key as it is the major environmental factor for improvement of livestock production performance. Farmers need to be trained on establishment and conservation of fodder crops with an emphasis with PRFs for improved feeding management (Mbinyo *et al.*, 2017). In addition, supplementation of low quality grass basal diets with legume forage has been shown to increase dry matter intake and production performance in goats (Abdulrazak *et al*., 1996; Kaitho, 1997). These responses have typically been attributed to the legume overcoming the depressing effect that low nitrogen

(N) concentration in pastures has on intake where the legume provide ruminally degradable N (Minson, 1990). Feeding systems that make greater use of locally grown feed resources such as protein-rich forages would provide sustainable alternatives to the more expensive cereal and oilseed-based concentrates. The use of herbaceous legumes such as Vetch and multipurpose trees such as Calliandra are viable alternatives of supplementing rumen degradable N and/or by-pass protein to dairy goats to increase intake of basal diets and therefore nutrient intake to boost production performance. Generally, good quality forage is high in protein and digestible nutrients, and low in fiber and lignin (Bakhashwain, 2010). The objective of the current study was to evaluate the effect of supplementing growing dairy goats fed Rhodes grass basal hay with Calliandra and vetch hay on growth performance.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experiment 1

Effect of supplementing Rhodes grass hay with dried Calliandra leaves and common vetch hay on feed intake and live weight gain of weaned cross-bred dairy goats

3.1.1 Study site

The study was conducted at Tatton Agricultural Park (TAP), Egerton University, Njoro. The farm is located in the Rift Valley region on the Eastern slopes of Mau Escarpment of the Great Rift Valley of East Africa, Njoro Sub-County in Nakuru County of Kenya. It is lies between latitude 0º 23'S and longitude 35º 57'E at an altitude of 2200 m and 2280 m above sea level. The area has a bimodal rainfall pattern with long rains starting from March to May, sometimes extending to June and short rains in September to November. The mean annual rainfall from the University's meterological station measured from 1977-2005 was 940 mm (Raude, 2006).

3.1.2 Animals and experimental diets

Twelve (12) male cross-bred (Toggenburg x Small East Africa goat) weaned goats aged between 3-4 months and an initial weight ranging between 11.5-12.6 Kg were used as experimental animals in the study. The initial weight for each goat was identified by taking weight for each goat for three consecutive days and the mean weight taken.

Rhodes grass (*Chloris gayana*) hay was used as the basal diet, while dried Calliandra (*Calliandra calothyrsus*) leaves and common Vetch (*Vicia sativa*) hay were used as the supplemental diets. Well cured Rhodes grass hay was sourced from Ngongogeri Farm of Egerton University and shredded into 2 cm size using a tractor driven forage shredder. The shredded hay was then stored in gunny bags. Vetch was grown at Kenya Agricultural and Livestock Research Organization (KALRO), Oljoroorok station and harvested at dough stage and then conserved as hay. The hay was then chopped into 2 cm size using an electric power fodder chopper and stored in gunny bags.

Calliandra, branches were harvested from mature shrubs grown at KALRO Oljoroorok. It was air-dried in a well-ventilated barn for 7-10 days. The leaves were separated from the branches by threshing manually to get the dried Calliandra leaves. The dried leaves were stored in gunny bags. The two forages were transported to the study site 2 weeks before commencement of the study. The feeds were stored under cool and well ventilated conditions for the entire experimental period. Each of the feed samples were hammer milled through a 1-2 mm screen and packed in sampling bottles for chemical analyses.

Rhodes grass hay was used as the basal diet to act as the control (T1); Supplemental diets were; dried calliandra leaves (T2) and common vetch hay (T3). Dry matter intake was calculated at 5% of the live weight of each goat being the higher DMI value reported for goats (Kieser, 2010). Each of the supplemental diets was fed at 30% of the total estimated DM intake for each goat, while the basal diet was availed *ad libitum*. The amount fed was adjusted at the beginning of each week to cater for the changes in live weight. The supplement was provided prior to the *ad libitum* feeding of the basal diet to ensure the goats consumed the entire supplement. The three dietary treatments were as shown in Table 3.1.

Table 3.1: Dietary treatment for Experiment 1

	Dietary composition (%)		
Ingredients	**T1**	**T2**	**T3**
Rhodes grass hay	100	70	70
Dried Calliandra leaves	0	30	0
Vetch hay	0	0	30
Total	**100 %**	**100 %**	**100 %**

3.1.3 Experimental design

A randomized complete block design (RCBD) and three dietary treatments were used. The three dietary treatments were randomly allocated to the animals in each of the four blocks. Blocking was based on liveweight of the animals. There were four animals for each of the dietary treatment. The animals were confined in individual, slatted, well-ventilated pens (Plate 2).

Plate 2: Goats feeding in individual, well ventilated slatted floor pens

Clean water and mineral lick were availed *ad libitum* to each goat individually. The goats were drenched with an anti-helmintics (10% albendazole®) for the control of endo-parasites while ecto-parasites were controlled fortnightly using an arcaricide (stelladone®). The initial 10 days were allowed for adaptation to the diets and then data collected for 8 weeks.

The feeds were offered twice a day at 07:30 and 14:00 hr. The whole portion of supplements was offered first at 07:30 hr. as a priority, while the basal diet was offered immediately the goat finished the supplement. At 14:00 hr, only the basal diet was offered depending on the morning intake. Rhodes grass hay was offered *ad libitum* so as to allow for about 10% refusals and as a way of ensuring that intake was not constrained by unavailability of the basal diet. The intake of both the basal and supplement for each animal was calculated and recorded daily. Refusals from the previous day's offer were collected from each goat, weighed and recorded. It was then sub-sampled, bulked and stored for further chemical analyses at the end of the collection period. At the end of every week on a designated day, each goat was weighed before feeding at 07:00 -07:30 hr. and weight of each goat recorded (Plate 3).

Plate 3: Weighing of the dairy goats in Tatton Agriculture Park, Egerton University

The total dry matter intake (TDMI) and the Crude Protein Intake (CPI) were calculated as follows:

a) TDMI=DMI of basal diet (g) + DMI of the supplement (g)

b) CPI= {DMI of basal diet (Rhodes grass hay) x CP % of basal diet} + {DMI of supplement x CP % of supplement}

3.1.4. Chemical analyses of experimental diets

The three experimental diets were subjected to proximate analysis where dry matter (DM), Crude protein (CP), Ether extract (EE), organic matter (OM) and ash content were determined according to the procedures outlined in AOAC (1990). Neutral detergent fibre (NDF), Acid detergent fiber (ADF) and Acid detergent lignin (ADL) were determined by the method of Goering & Van Soest (1994) in determining the cell wall constituents (CWC) and cell contents (CC) of each diet. Hemicellulose and cellulose was calculated as follows;

a) Hemicellulose=NDF-ADF

b) Cellulose=ADF-ADL

3.1.5. *In-vitro* gas production and rumen liquor collection

Rumen liquor was collected 2 days before the end of the feeding trial using a stomach tube early in the morning before feeding the goats (Plate 4). The pH of each sample collected was measured immediately using a pH meter.

Plate 4: Collection of rumen liquor from the goat

In *vitro gas* production was conducted for all the experimental diets according to procedure of Menke and Steingass (1988) to measure apparent digestibility. Feed samples of Rhodes grass hay, dried Calliandra leaves and common Vetch hay were incubated *in-vitro* with rumen fluid-buffer mixture in 100 ml calibrated glass syringes. The rumen liquor collected was properly mixed and filtered through a metallic sieve (1 mm sieve). A stream of carbon dioxide gas (CO_2) was made to pass through the sieved rumen liquor until the completion of inoculation. Incubation was conducted using three replicates per treatment. 100 ml capacity calibrated glass syringes were used and the piston of the syringes was lubricated with Vaseline Jelly. Feed samples were weighed each containing 0.2 g. The piston was withdrawn and later inserted after introduction of the feed samples. The inoculum of 30 ml was introduced through the silicon tube fitted into the top of the syringe containing 200 mg the test sample. The content was agitated while the piston of the syringe was pushed off to eliminate the air bubbles and after which the silicon tube was tightened with metal clip, leaving a 2 cm length of the silicon tube above the clip (Plate 5). The prepared syringes were placed in the incubation maintained at 39^0C Readings of gas produced were recorded at 0, 3, 6, 9, 12, 24, 48, 72 and 96 hr after incubation.

Plate 5: Adjusting calibrated glass syringe during *in-vitro* gas production

Cumulative gas production data were then fitted in the model of Ørskov and McDonald (1979). The exponential equation $Y = a+b\ (1-e^{-ct})$, where Y is the gas produced at the time t and a+b is the potential gas produced (ml), c is the gas production rate constant and t is the incubation time.

A graph was plotted to show the trend of the incubation for the *in-vitro* gas production characteristics of the basal diet (Rhodes grass hay) and supplemental diets. The gas produced provided a useful basis from which Metabolizable energy (ME) and organic matter digestibility (OMD) were calculated.

3.1.6. Statistical analysis

The data collected from the experiment was subjected to analysis of variance (ANOVA) using the General linear model (GLM) procedures of statistical analysis SAS (2008). An F-test at 5% probability level was used to test for significance and means separation was done by least significance difference (LSD).

Statistical model

$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon ij$

Where:

Y_{ij} = observation of i^{th} dietary treatment in the j^{th} block.

μ= Overall mean

α_i= effect of i^{th} dietary treatment, where i= {1,2,3}

β_j= effect of j^{th} block, j= {1, 2, 3,4}

ε_{ij}= random error component

3.2 Experiment 2

Effect of supplementing Rhodes grass hay with mixed ration of dried Calliandra leaves and common Vetch hay on feed intake and live weight gain of growing cross bred dairy goats

3.2.1. Study site

The study was conducted at Tatton Agricultural Park (TAP) as explained in experiment 1.

3.2.2. Animals and experimental diets

The experimental animals were twelve (12) male cross-bred (Toggenburg x Small East Africa goat) growing goats aged between 6-7 months weighing between 12.7-14.0 Kg.

The feeds described in experiment 1 were used in this experiment as follows: Rhodes grass hay (D1) was used as the control, while the dried *Calliandra calothyrsus* leaves and the common Vetch hay were used to formulate three supplemental diets as follows: 75% dried Calliandra leaves and 25% common Vetch hay (D2); 50% dried Calliandra leaves and 50% common Vetch hay (D3); and 25% dried Calliandra leaves and 75% common Vetch hay (D4). Dry matter intake was calculated at 5% of the live weight of each goat being the higher DMI value reported for goats (Sauvant *et al*., 1991; Kieser, 2010). Each of the supplemental diets was fed at 30% of the estimated total DM intake for each goat, while the basal diet was availed *ad libitum*. The amount fed was adjusted at the beginning of each week to cater for any changes in live weight. The supplement was provided prior to the *ad libitum* feeding of the basal diet to ensure the goats consumed the entire supplement. The four dietary treatments were as shown in Table 3.2.

Table 3.2: Dietary treatments for Experiment 2

	Dietary Composition (%)			
Ingredients	**T1**	**T2**	**T3**	**T4**
Basal hay	100	70	70	70
Dried Calliandra leaves	0	22.5	15	7.5
Common Vetch hay	0	7.5	15	22.5
Total	**100 %**	**100 %**	**100 %**	**100 %**

3.2.3. Experimental design

A randomized complete block design (RCBD) with three blocks based on live weight and four treatments was used. The dietary treatments were randomly allocated to the animals. The animals were confined in individual, well-ventilated, slatted pens. Clean water and mineral lick were availed *ad libitum* to each goat individually. The goats were drenched with an anti-helmintics (10% albendazole®) for the control of endo-parasites and ecto-parasites controlled fortnightly using an arcaricide (stelladone®). The initial 10 days were allowed for adaptation to the diets and then data collected for 8 weeks.

The feeds were offered twice a day in the morning at 07:30 and at 14:00 hr, while the supplements were offered first as a priority at 07:30 hr. The basal diet was offered immediately the goats finished the supplement. At 14:00 hr, only the basal diet was offered depending on the morning intake. Rhodes grass hay was offered *ad libitum* so as to allow for about 10% refusals and as a way of ensuring that intake was not constrained by unavailability of the basal diet. The intake of both the basal and supplement for each animal was recorded daily. The refusals from the previous day's offer were collected from each goat, weighed and recorded, it was then sub-sampled, bulked and stored for further chemical analyses at the end of the collection period. Each goat was weighed weekly using a well calibrated weighing scale on one day of the week before feeding the goats at 07:00 -07:30 hr and recorded.

The total dry matter intake (TDMI) and the Crude Protein Intake (CPI) were calculated as follows:

a) TDMI=DMI of basal diet (g) + DMI of the supplement (g)

b) CPI= {DMI of basal diet (Rhodes grass hay) x CP % of basal diet} + {DMI of supplement x CP % of supplement}

3.2.4. Chemical analyses of experimental diets

The four experimental diets were subjected to proximate analysis where dry matter (DM), crude protein (CP), ether extract (EE), organic matter (OM) and ash content was determined according to the procedures outlined in AOAC (1990). Neutral detergent fiber (NDF), Acid detergent fiber (ADF) and Acid detergent lignin (ADL) determined by the method of Goering and Van Soest (1994). Hemicellulose and cellulose was calculated as follows;

a) Hemicellulose=NDF-ADF

b) Cellulose=ADF-ADL

3.2.5 *In-vitro* gas production and rumen liquor collection

Rumen liquor was collected 2 days before the end of the feeding trial using a stomach tube early in the morning before feeding the goats. The pH of each sample collected was measured immediately using a pH meter.

In *vitro gas* production was conducted for all the experimental diets according to procedure of Menke and Steingass (1988) as in Experiment 1.

3.2.6. Statistical analysis

The data collected from the experiment was subjected to analysis of variance using the General linear model (GLM) procedures of statistical analysis SAS (2008). An F-test at 5% probability level was used to test for significance and means separation was done by least significance difference (LSD).

Statistical model

$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon ij$

Where:

Y_{ij} = observation of i^{th} dietary treatment in the j^{th} block.

μ= Overall mean

α_i= effect of i^{th} dietary treatment, {i=1, 2, 3, 4}

β_j= effect of j^{th} block, {j=1,2,3}

ε_{ij}= random error component

CHAPTER FOUR

RESULTS

4.1. Experiment 1: Effect of supplementing Rhodes grass hay with dried Calliandra leaves and common Vetch hay on feed intake and live weight gain of weaned cross-bred dairy goats

4.1.1. Chemical composition of basal diet and supplemental diets

The proximate chemical composition of Rhodes grass hay (basal diet) and supplemental diets used is given in Table 4.1.

Table 4.1: Proximate Chemical Composition of the basal Rhodes grass hay and supplemental diets of dried calliandra leaves and common vetch hay (g kg^{-1} DM)

Parameter	Rhodes grass	Calliandra	Vetch
DM	930.8	892.6	858.1
OM	824.7	833.5	745.5
CP	79.5	229.8	227.2
Ash	114.0	66.2	131.2
EE	65.3	52.5	78.7
NDF	690.8	242.5	417.9
ADF	367.8	230.1	311.1
ADL	129.7	107.6	71.2
Hemicellulose	323.0	12.4	106.8
Cellulose	238.1	122.5	239.9

DM=Dry matter, OM=Organic matter, CP=Crude protein, EE=Ether extracts, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, ADL=Acid detergent lignin.

Rhodes grass hay had the highest DM content and common vetch hay recording the lowest among the diets. The CP content in the basal diet was lowest among the diets, while supplemental diets had similar amounts, 229.8 and 227.2 g kg^{-1} DM for Calliandra and vetch respectively. Common Vetch hay had the highest ash content of 131.0 g kg^{-1} DM followed by Rhodes grass hay with 11.4 g kg^{-1} DM while Calliandra recorded the lowest ash content in this study. There was a similar trend for ether extract with Vetch hay having the highest and Calliandra the least content. Rhodes grass hay had the highest NDF and ADL, while common vetch hay had the lowest lignin content.

4.1.2. Voluntary feed intake and pH of rumen liquor

The pH of rumen liquor which was extracted from goats fed the dietary treatments ranged from 6.8-7.0 which was within the normal range required for optimal microbial fermentation activity in the rumen (Table 4.2).

The total dry matter intake (TDMI) and CPI showed that goats supplemented with dried Calliandra leaves had the highest TDMI (527.3 g/day) followed by those supplemented with common vetch hay (Table 4.2). The un-supplemented goats recorded the lowest TDMI (290.4 g/day). The TDMI was significantly different ($P < 0.05$) for the supplemented goats compared to those fed basal diet only. However, the TDMI among the supplemented goats was not significantly different ($P > 0.05$). Supplementation enhanced basal feed intake significantly ($P < 0.05$) in the present study which was 24.2 % and 16.9% higher for those goats on T2 and T3 respectively compared to those on basal diet (T1).

The voluntary feed intake relative to the live weight was significant ($P<0.05$) for goats under supplemental diets (3.3 percent and 3.4 percent for goats on T2 and T3 respectively) compared to those fed on basal diet (2.8 percent). The supplemental diets significantly increased ($P<0.05$) CP intake from 23.1 g to 66.9 and 61.8 g/day for T1 (Control), T2 and T3 respectively. However, the CP intake for supplemented goats was not significantly different ($P>0.05$).

Table 4:2: Total Dry Matter Intake (TDMI), Crude Protein Intake (CPI) and pH of rumen liquor for dairy goats fed Rhodes grass hay supplemented with dried *Calliandra calothyrsus* leaves and *Vicia sativa* hay

	Dietary Treatments			
Parameter	**T1(Control)**	**T2**	**T3**	**SEM**
DMI (g/day)				
Intake of Basal diet (Rhodes grass hay)	290.4^{a}	360.8^{b}	339.2^{b}	11.2
Intake of Supplement (Calliandra and vetch)	0.0	166.4	153.1	7.9
TDMI (g/day)	290.4^{a}	527.3^{b}	492.3^{b}	23.5
TDMI as % Lwt	2.8^{a}	3.3^{b}	3.4^{b}	0.2
CPI (g/day)	23.1^{a}	66.9^{b}	61.8^{b}	2.8
pH of rumen liquor	6.9	7.0	6.8	0.2

^{ab} means with different superscripts within a row are significantly different at P< 0.05. TI= Basal diet of Rhodes grass hay; T2= Rhodes grass hay supplemented with *Calliandra calothyrsus* dried leaves; T3= Rhodes grass hay supplemented with Vetch hay; SEM= Standard Error of the Mean.

4.1.3. *In-vitro* gas production

In-vitro gas production for the experimental diets is shown in Table 4.3. Vetch hay had a notable initial gas production where it produced 4.4 ml/200mg DM, followed by Rhodes grass hay (3.0ml/200mg DM), while Calliadra had the least (0.8ml/200mg DM). The same trend was on the net gas produced with Vetch hay producing the highest net gas (9.2 ml/200mg DM). At 48hr of incubation, all the three diets produced maximum and thereafter started to decline gradually (Figure 4.1).

Table 4:3: *In Vitro* gas production (ml/200mgDM) of Rhodes grass hay, Dried *Calliandra calothyrsus* leaves and common vetch hay and calculated ME and OMD

	Gas production (hr)					Degradation constants				ME	OMD	RSD
	6	24	48	72	96	a	b	C	a+b	(MJ/Kg DM)	(%)	
Rhodes grass	8.6	23.9	30.0	31.8	33.9	3.0	5.1	5.8	8.1	14.2	46.22	7.8
Calliandra leaves	7.8	22.2	33.4	39.3	41.1	0.8	4.2	6.5	5.0	14.4	49.4	3.9
Vetch hay	13.1	34.6	41.9	43.8	45.3	4.4	4.8	10.9	9.2	14.2	57.2	3.8

a, b, c are constants: a=Initial gas production, b=Gas produced during incubation, c=Gas production rate constant (Fraction/hour), a+b=Net gas produced in the equation (Ørskov and McDonald, 1979), RSD=Residual Standard Deviation, calculated ME (MJ/kg DM) =14.78-0.0147ADF and OMD48: Organic matter digestibility calculated from the equation; OMD (%) =18.53+0.9239(gas produced at 48hr) + 0.054CP (Menke &Steingass, 1988).

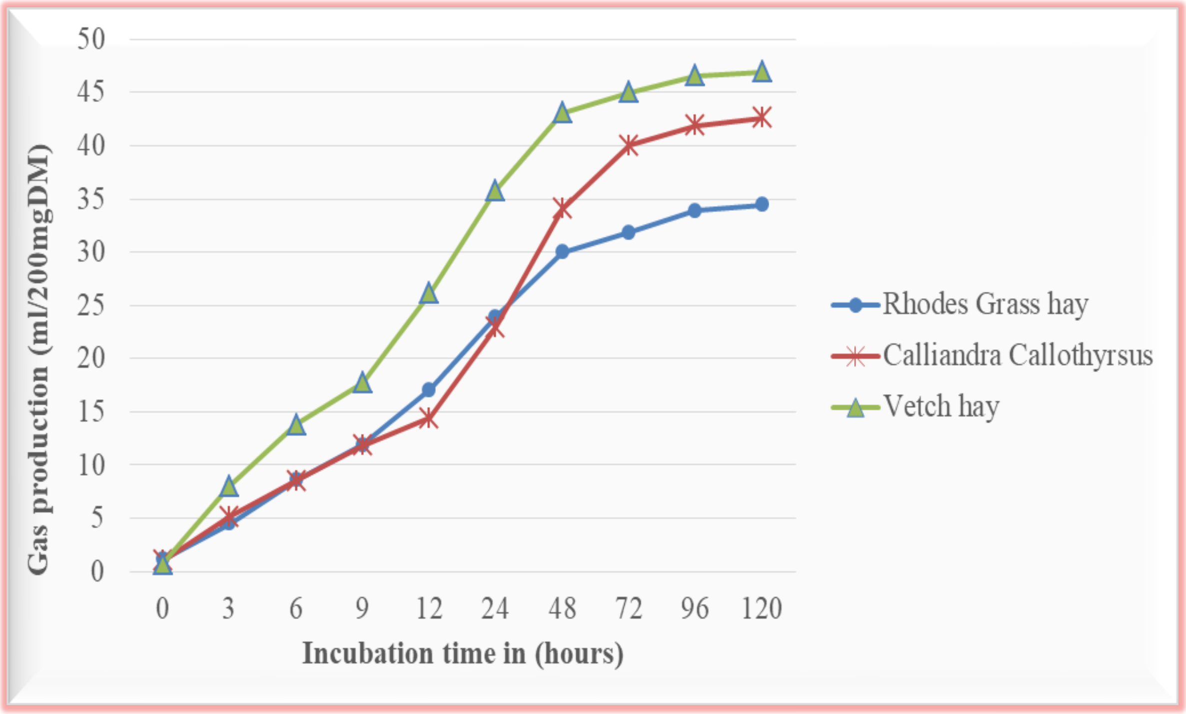

Figure 4.1: *In-Vitro* gas production on Rhodes grass hay, *Calliandra calothyrsus* dried leaves and vetch hay in buffered rumen fluid.

4.1.4. Growth performance

The live weight change and the average daily gain is shown in Table 4.4. Both the total live weight change and ADG for supplemented goats was significantly different (P<0.05) from those fed the basal diet but not significantly different (P>0.05) amongst supplemented goats. Goats supplemented with dried Calliandra leaves had the highest weight gain (3.4 kg) and growth rate (60.9 g/day) followed by those supplemented with common vetch hay (2.9 kg LWT; ADG of 51.1g/day) in the present study. The control group fed on basal Rhodes grass hay lost weight (-1.1 kg) and had a negative daily weight gain (-19.5 g/day).

Table 4.4: Total live weight change and Average Daily weight gain (ADG) of weaned dairy goats fed Rhodes grass hay and supplemented with dried *Calliandra calothyrsus* and *Vicia sativa* hay.

	Dietary Treatments			
Parameter	**T1**	**T2**	**T3**	**SEM**
Initial body weight (kg)	11.5	12.6	12.2	0.3
Final body weight (kg)	10.4^{a}	16.0^{b}	14.7^{b}	0.6
Live weight change (kg)	-1.1^{a}	3.4^{b}	2.9^{b}	0.5
ADG (g/day)	-19.5^{a}	60.9^{b}	51.1^{b}	9.4

^{ab} means with different superscripts within a row are significantly different at (P<0.05). SEM=Standard Error of the Mean. ADG=Average Daily Gain.

4.2. Experiment 2: Effect of supplementing Rhodes grass hay with mixed ration of dried Calliandra leaves and common Vetch hay on feed intake and live weight gain of growing cross bred dairy goats

4.2.1. Chemical composition of basal and supplemental diets

The chemical composition of the experimental diets is as shown in Table 4.5.

Table 4.5: Chemical composition of basal and supplemental diets (g kg^{-1}) used in Experiments 2

	Dietary Compositions			
Parameter	**D1**	**D2**	**D3**	**D4**
DM	930.8	893.1	889.6	878.8
OM	824.7	818.1	811.9	782.0
CP	79.5	223.2	215.4	216.9
Ash	114.0	84.0	87.3	110.1
EE	65.3	43.4	30.1	24.5
NDF	690.8	396.2	388.0	429.8
ADF	367.8	248.8	274.8	325.4
ADL	129.7	56.2	116.8	122.1
Hemicellulose	323.0	147.4	113.2	104.4
Cellulose	238.1	192.6	158.0	203.3

DM=Dry matter; OM=Organic matter; CP=Crude protein; EE=Ether extracts; NDF=Neutral detergent fiber; ADF=Acid detergent fiber; ADL=Acid detergent lignin; Dried *Calliandra calothyrsus* leaves(C); Common Vetch hay (V); D1=Rhodes grass hay; D2=Ration combining 75%C+25% V; D3= Ration combining 50%C+50% V; D4= Ration combining 25%C+75% V.

Rhodes grass hay had the highest DM content (930.8 g kg^{-1}) and D4 had the lowest (878.8 g kg^{-1}). The OM for D1, D2 and D3 were almost the same though higher for D1 (824.7 g kg^{-1}) and lowest for D4 (782.0 g kg^{-1}). The basal diet had the least CP content (80 g kg^{-1}) while the supplemental diets had higher and almost similar CP content though slightly higher for D2 (223.2 g kg^{-1}). Rhodes grass hay had the highest NDF and ADL content while D3 reported the lowest NDF content (388.0 g kg^{-1}) in this study. Supplemental diets had lower ADL content than the basal diet with D4 reporting the highest content (122.1 g kg^{-1}). Ash content for D1 and D4 was higher and almost similar and lowest for D3. The lowest ether extract was in D4 and highest for D1.

4.2.2. Voluntary feed intake

The total dry matter intake, the basal and supplement intake and the crude protein intake is shown in Table 4.6.

Table 4.6: Total Dry Matter Intake (TDMI), Crude Protein Intake (CPI) and pH of rumen liqour of growing goats fed a basal diet of Rhodes grass hay and supplemented with mixed rations of Dried *Calliandra calothyrsus* leaves and Common Vetch Hay

	Dietary Treatment				
Parameter	**T1**	**T2**	**T3**	**T4**	**SEM**
DMI (g/day)					
Intake of Basal diet	424.1^{a}	584.2^{b}	617.2^{b}	551.9^{ab}	30.1
Intake of Supplement	0.00^{a}	191.9^{b}	199.3^{b}	177.8^{b}	12.3
TDMI (g/day)	424.1^{a}	776.1^{b}	816.5^{b}	729.7^{b}	38.3
TDMI (% Lwt)	3.0	4.4	4.5	4.2	
CPI (g/day)	33.7^{a}	74.0^{b}	76.2^{b}	68.3^{b}	3.6
pH	6.9	7.1	6.9	7.2	0.2

[ab] means with different superscripts within a row are significantly different at P< 0.05. SEM=Standard Error of the Mean. TI= 100% Basal diet (Rhodes grass hay; T2= Basal diet + 30% (Ration combining 75% Calliandra (CC) + 25% Vetch (CV): T3= Basal + 30% (Ration combining 50% CC+50% CV); T4= Basal + 30% (Ration combining 25% CC+75% CV).

Supplementation of goats significantly increased ($P<0.05$) TDMI. Goats in T3 had the highest total daily DM intake (816.5 g/day) compared to an intake of 424.1 g/day for the un-supplemented animals. Supplementation enhanced basal feed intake by 37.8%, 45.5% and 30.1% for goats in T2, T3 and T4 respectively. The basal diet intake was significantly higher ($P<0.05$) for goats in T2 and T3 and not significantly different ($P>0.05$) for those in T4. The crude protein intake for the supplemented goats was significantly different ($P<0.05$) from goats fed the basal diet increasing from 33.7 g/day to 74.0 g/day, 76.2 g/day and 68.3 g/day for T1, T2, T3 and T4 respectively. TDMI as percent live weight for all the goats ranged between 3.0 to 4.5 percent which is within the range for dairy goats.

4.2.3. ***In-Vitro*** **gas production (ml/200mgDM) and rumen pH**

The rumen pH for goats in T1 and T3 were similar at 6.9 but those in T2 and T4 had slightly higher pH of 7.1 and 7.2 respectively (Table 4.6).

The *In-vitro* gas production is given in Table 4.7. T4 the mixed ration which had more common Vetch hay (75%) had the highest net gas produced (5.2 ml/200mg DM) and highest gas production rate constant (12.6 ml/200mg DM) followed by T2. Rhodes grass hay in T1 recorded a net gas of 3.9 ml/200mgDM while T3 produced the least net gas. Cumulative gas production trends (Figure 4.2) showed that T3 had the highest cumulative gas production followed by T4, while T2 had the least and lower than that produced by Rhodes grass hay (T1) which was the basal diet in the study.

Table 4.7: *In Vitro* gas production (ml/200 mgDM) of Rhodes grass hay and treatment rations from Dried *Calliandra calothyrsus* leaves and common Vetch hay.

	6	**24**	**48**	**72**	**96**	**a**	**B**	**c**	**a+b**	**RSD**
T1(Rhodes grass)	8.6	23.9	30.0	31.8	33.9	1.2	2.7	0.1	3.9	2.3
T2(Rhodes grass +30% D2)	5.7	17.8	22.1	23.6	24.2	2.2	2.8	5.2	5.0	3.0
T3(Rhodes grass +30% D3)	13.1	34.5	41.8	44.8	46.8	0.4	2.4	5.5	2.8	2.0
T4 (Rhodes grass+30% D4)	11.6	32.3	39.6	42.6	43.9	0.8	4.4	12.6	5.2	3.2

a, b, c are constants in the equation (Ørskov and McDonald, 1979: a=Initial gas production, b=Gas produced during incubation at time t, c=Gas production rate constant (Fraction/hour), RSD=Residual Standard Deviation, a+b=Net gas produced.

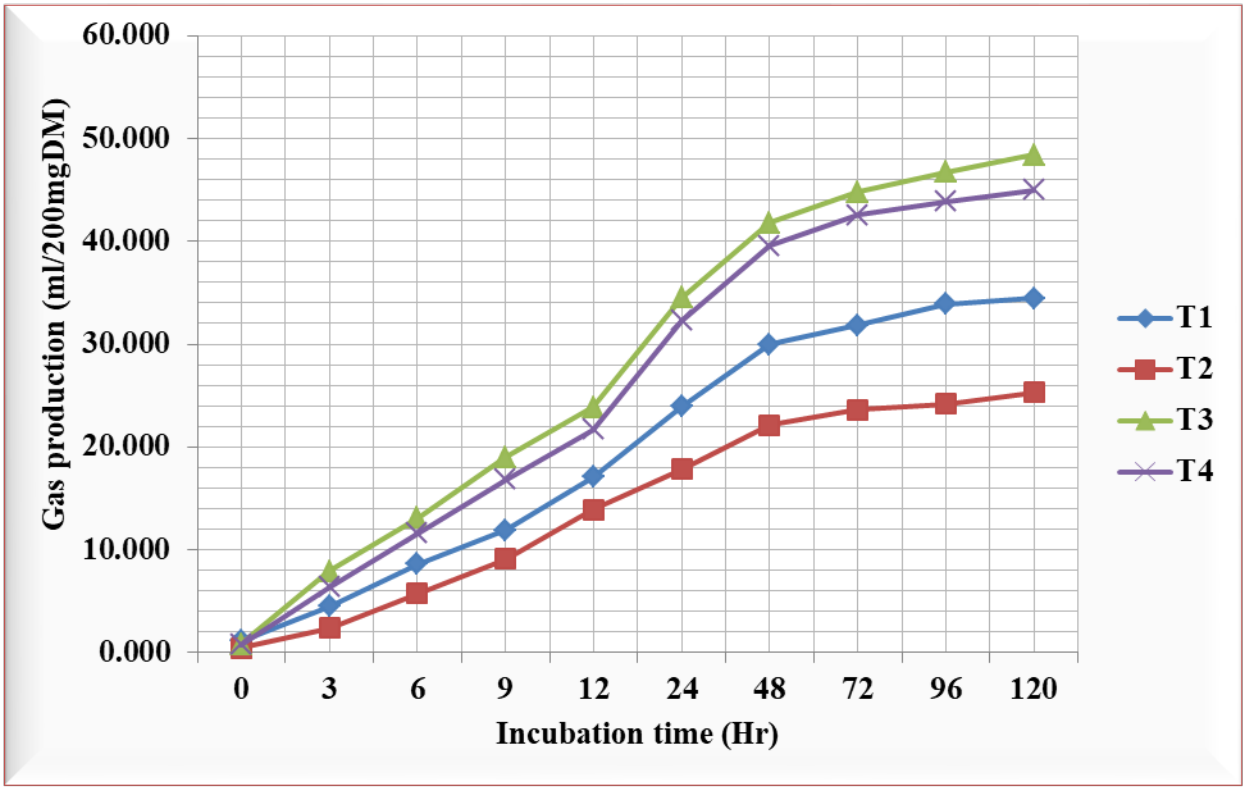

Figure 4.2: Pattern of *in Vitro* cumulative gas production on Rhodes grass hay, treatment rations of *Calliadra calothyrsus* dried leaves and vetch hay in buffered rumen fluid.

4.2.4. Growth performance

Growth performance for goats is as shown in Table 4.8 and Figure 4.3. Supplementation significantly increased ($P<0.05$) the total live weight gain from 0.6 kg to 5.0 kg, 4.3 kg and 3.7 kg for T1, T2, T3 and T4 respectively. However, though goats in T2 gained the highest total weight, it was not significantly different ($P>0.05$) from that of T3 and T4. Similarly, average daily gain was significantly higher ($P<0.05$) for goats fed supplements, T2 having the highest ADG (89.9 g/day), while goats in T1 reported the lowest gains (20.8 g/day). Generally, even though goats fed on the basal diet had an overall gain in weight, the goats lost weight towards the end of the experimental period, while the supplemented goats maintained an increase in weight (Figure 4.3) throughout the study period.

Table 4.8: Live weight gain and Average Daily weight gain (ADG) of growing dairy Goats fed basal diet of Rhodes grass hay and supplemented with mixed rations of dried *Calliandra calothyrsus* leaves and Common Vetch hay

	Dietary treatment				
Parameter	**T1**	**T2**	**T3**	**T4**	**SEM**
Initial body weight (kg)	13.7	12.7	14.0	13.8	0.7
Final body weight (kg)	14.3^{a}	17.7^{b}	18.3^{b}	17.6^{b}	1.1
Total weight change (kg)	0.6^{a}	5.0^{b}	4.3^{b}	3.7^{b}	0.6
ADG (g/day)	20.8^{a}	89.9^{b}	76.2^{b}	66.4^{b}	12.6

^{ab} means with different superscripts within a row are significantly different at 5%. SEM=Standard Error of the Mean. ADG=Average Daily Gain.

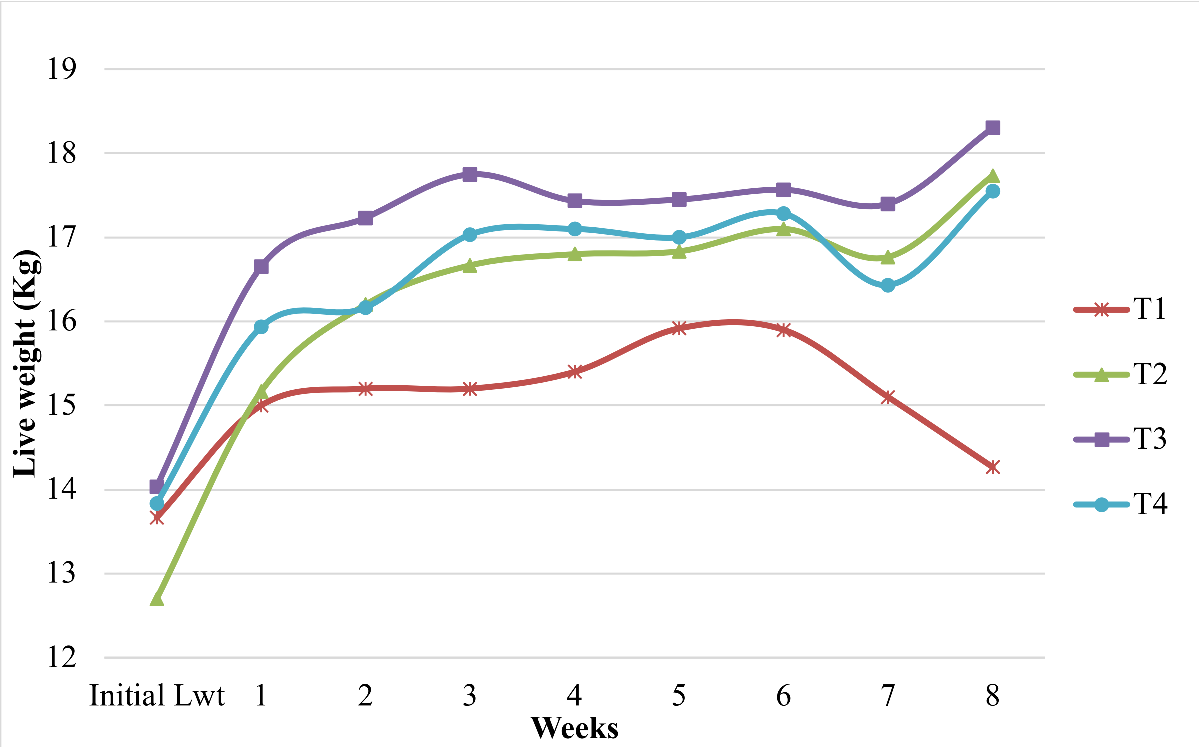

Figure 4.3: Weekly live weight gain for growing dairy goats fed basal diet of Rhodes grass hay and supplemented with mixed rations of dried Calliandra calothyrsus leaves and common vetch hay

CHAPTER FIVE

DISCUSSION

5.1 Chemical composition of Rhodes grass hay, *Calliandra calothyrsus* dried leaves, common vetch hay and mixed rations

The DM content of the Rhodes grass hay observed in this study of 920 g kg^{-1} DM was consistent with that reported in literature of 849 g kg^{-1} DM (Biwott, 2000). However, the result differed with that reported by Ondiek *et al*. (1999) of 484 g kg^{-1} DM. The difference may be due to the stage of maturity of the grass since the more mature the grass is, the higher the DM content while, the less mature the lower the DM. The DM for dried *Calliandra calothyrsus* leaves was close to that reported by others of 920 and 909 g kg^{-1} DM (Kaitho & Kariuki, 1998; Wambui *et al.*, 2006). Common vetch recorded 858.1 g kg^{-1} DM almost similar to a previous study which recorded 901.0 g kg^{-1} DM (Lanyasunya *et al*., 2006).

The CP of Rhodes grass hay (80 g kg^{-1}) was within the range reported for grass hays of 40-112 g kg^{-1} DM (Van soest, 1994) and also similar to those reported in earlier studies (Biwott, 2000; Kinuthia *et al*., 2007) but differed with 48 and 43 g kg^{-1} reported by Ondiek *et al*. (1999) and Woyengo *et al*. (2004). *Calliandra calothyrsus* and vetch hay recorded similar CP content (230 g $kg^{-1)}$ which was within the reported range of legume forages of 200-300 g kg^{-1} DM by Tuwei *et al*. (2003) and similar to those from other reports (Rebole *et al.,* 2004; Wojciech *et al.,* 2014). However, these results differed slightly with those of Wambui *et al.* (2006) of 188.8 g kg^{-1} DM, while Kaitho *et al.* (1993) reported higher CP content (280 g kg^{-1} DM). Some studies which used common Vetch forage with grain reported higher CP of 290 and 315 g kg^{-1} DM (Hadjipanayiotou & Economides, 2001). This is associated with the fact that grains of common vetch have at least 2.5 times higher CP than cereal grains under similar growing conditions attaining 31.4-35.7% and 24-27%, respectively (Hadjipanayiotou & Economides, 2001).

Rhodes grass hay had the highest NDF of 690.8 g kg^{-1} DM as reported for grass hays compared to legume forages with *Calliadra calothyrsus* recording the lowest with 242.5 g kg^{-1} DM while, common Vetch hay had 417.9 g kg^{-1} DM. Previous studies recorded higher NDF for Calliandra of 495 g kg^{-1} DM (Kaitho, 1997) and 307.9 g kg^{-1} DM (Wambui *et al.*, 2006). This could be associated with the stage of growth since the more mature a forage is, the more the cell wall content and therefore the higher the NDF values.

The NDF values for common vetch hay in this study compared well with that reported in literature of 465.0 g kg^{-1} DM (Lanyasunya *et al*., 2006) but higher than that reported in previous studies of 173.5 g kg^{-1} DM and 404.0 g kg^{-1} DM (Hadjipanayiotou & Economides, 2001; Rebole *et al*., 2004). Among the diets, the NDF content for Calliandra was within the range of 200-350 g kg^{-1} DM reported by Norton (1994) within which digestibility is enhanced. The high lignin content in Rhodes grass hay was consistent with previous studies that show grasses having higher lignin content than legumes (Dereje & Temesegen, 2016; Henze *et al.,* 2016).

The combinations of the different levels of the two fodder legumes (*Calliandra calothyrsus* leaves and common vetch hay) that made the supplemental diets in the study had a comparable CP content (215.4 to 223.2 g kg^{-1} DM) which was within the range for legume fodders. The OM and DM content of D3 and D4 was higher compared to that of pure common vetch hay associated to the combination of the diets with Calliandra. This was a good indication that combining the supplemented forages in this case improved the nutritive value of the feeds. This was consistent with report by Asaulu *et al.* (2011) that evaluated nutritional synergies between equal but separate proportions of *Moringa Oleifera* (MO) with *Leuceana leucocephala* (LEU) and *Gliricidia sepium* (GLI) fodders fed to West Africa Dwarf goats where the 50% MO: 50% LEU and 50% MO: 50% GLI fodder combinations appeared promising as protein supplements and recommended the use of combinations of MO with either LEU or GLI by small ruminants. The nutritional interactions caused by feeding of diverse browse foliage as opposed to single foliage can alter the type and number of microorganisms in the rumen and subsequently have an effect upon nutrient digestion. Muelleo-Harvey (2006) reported that feeding browse foliage mixtures is an effective feeding regime that can compensate nutrient imbalances and dilute any negative nutritional effects of condensed tannins as compared with tanniferous browses fed as sole diets. The NDF for the mixed rations was higher than for the pure fodders which were associated to the presence of common vetch in the diets which had relatively higher NDF content than Calliandra. The inclusion of vetch in the diets increased the ash content of D2 and D3, while the ash content of the basal diet and D4 were similar.

5.2 Voluntary feed intake, rumen pH and *In-Vitro* gas production

The pH of rumen liquor was consistent with earlier studies and is within the normal range of 6.0-7.0 which is considered optimal for rumen function (Muia, 2000; Woyengo *et al*., 2004). The present study showed that there was significant increase in TDMI when weaned male dairy goats were supplemented with either dried Calliandra leaves or common vetch hay (527.3 g/day and 492.3 g/day, respectively) than those goats whose sole diet was basal diet of Rhodes grass hay which recorded 290.4 g/day.

This was consistent with earlier studies where dairy goats were supplemented with other PRFs. Ondiek *et al.* (2013) reported TDMI of 444 g/day and 442 g/day for growing Small E. Africa goat offered maize (*Zea may*) stover as a basal diet and supplemented with *Balanites aegyptiaca* and *Acacia tortilis* leaf forages respectively, up from 294 g/day. Cross-bred (Toggenburg x Saanen) dairy goat kids fed Rhodes grass as basal diet and the supplemented with *Gliricidia sepium* reported a TDMI of 604 g/day compared to 474 g/day for those on basal diet intake (Ondiek *et al.,* 1999). Kinuthia *et al.* (2007) reported a higher organic matter intake for weaner goats supplemented with graded levels of Calliandra and Lucerne (317 to 579 g/day) than Rhodes grass hay basal diet.

The crude protein intake (CPI) of 61.75-66.94 g/day for the supplemented goats and that of basal diet of 23.1 g/day was consistent with that reported by Wambui *et al.* (2006). The enhanced intake can be attributed to the additional supply of rumen degradable N supplied by the PRFs which enhance the activities of the microorganisms in the rumen thus increasing organic matter digestibility and, therefore, feed intake. Since the level of NDF in an animal ration normally influences the animals feed intake, the high NDF content of Rhodes grass hay (742.1 g kg^{-1}) is a factor that resulted to reduced DMI for the un-supplemented goats compared to the supplemented animals whose diets recorded low NDF values. It also follows that the supplemental diets could have had a higher feeding value than Rhodes grass hay since the higher percentage of cell contents is a good index of a nutritive value of a feed. Supplementing goats with dried *Calliandra calothyrsus* leaves recorded a higher DMI though it was not significantly different from those supplemented with Vetch hay.

Menke and Steingas (1988) indicated that the quantity of gas produced during an *In-vitro* incubation of a substrate is closely related to its digestibility and consequently to its energetic value, thus Vetch hay could have had the highest digestibility in the present study and the least digestible being Calliandra. The high rate of gas production by common vetch hay indicated that vetch hay was highly digestible than both the basal and Calliandra. The low digestibility of Calliandra is consistent with earlier studies (Tuwei *et al.,* 2003). *Calliandra calothyrsus* is reported to contain a wide variation of condensed tannins ranging between 1.5 to 19.4 percent and high levels of over 11% may reduce digestibility of protein in livestock (Fact Sheet, 2016).

However, despite the indication of low digestibility of *Calliandra calothyrsus*, the present study showed the best performance of goats supplemented with dried *Calliandra calothyrsus* leaves in both TDMI and ADG which has also been reported in previous studies (Tuwei *et al.,* 2003; Nyeko *et al.,* 2004; Dev *et* *al.,* 2008; Pathak, 2010). This cannot be well explained but it can be associated with the presence of condensed tannins which may prevent excessive rumen degradation of dietary protein hence increasing protected (by-pass) proteins which are utilized in the lower gut (Tandon & Siddique, 2016). Pathak (2013) concluded that low to moderate (1-4 % DM) use of condensed tannins supplementation improves nutrient utilization, productive performance and immunological response in small ruminants. Most of these positive effects in ruminants' nutrition are associated with great affinity of the leaf portion by condensed tannins after mastication (Ramírez Restrepo *et al.,* 2005). The ME of Calliandra (14.41 MJ/Kg DM) was consistent with earlier studies (Wambui, 2006) and was higher than that of Rhodes grass hay, therefore more energy was available to the supplemented goats than those on basal diet.

On TDMI, significantly higher intake was observed for supplemented goats than those fed the basal diet. This was consistent with earlier reports (Okello *et al*., 1996; Wambui *et al*., 2006; Osuga *et al*., 2012; Ondiek *et al*., 2013; Pandey *et al*. 2013). However, the study reported higher intake which differed with those reported earlier (Asaula *et al*., 2011; Sultana *et al*., 2012). Supplementation enhanced the basal diet and crude protein intake significantly. This agrees with Kaitho (1997) that supplementation can maintain or enhance feed intake. The high crude protein level of supplemental diets boosts degradable N in the rumen thus enhancing the intake by availing the much needed nitrogen (N) for utilization by the rumen microbes, especially cellulolytic bacteria. The lower NDF content in the supplemental diets then indicated a higher nutritive value of the supplemental diets. The CPI for supplemented goats (68.3 to 76.15 g/day) compares well with the 66.4 to 75.7 g/day CPI for goats that were supplemented with concentrate rations at 250 g and 300 g fed a green grasses *ad libitum* (Sultana *et al*., 2012).

The use of mixed rations of CC and CV in supplementing Rhodes grass in dairy goat feeding significantly improved growth rate in terms of total weight gain and ADG over the experimental period. The total weight gain of between 3.7 to 5.0 kg was comparable to that reported by Okello *et al*. (1996) where goats fed elephant grass and supplemented with cottonseed cake gained 5.6 kg. Sultana *et al*. (2012) reported a total weight gain of 5.3 kg. The ADG of 66.4 to 89.9 g/day was consistent with that reported by Luo *et al*. (2004a) for a post weaning growth rate of between 50-100 g/day for dairy goats. Pandy *et al*. (2013) reported ADG of 56.8-64.6 g/day while 50 g/day was reported by Niang *et al*. (1996). But results of this study differed with those reported in some past studies on goats where lower ADG were reported. For example, Sultana *et al*. (2012) reported 35.1 to 43.8 g/day, Njarui *et al*. (2003) reported 31.25 g/day, while Ondiek *et al*. (2013) reported 15.7-20.3 g/day. The difference is mainly associated with the quality of both basal diet and the supplemental diets in terms of the CP content, NDF levels and the digestibility. The diets in the present study had higher CP for the basal diet (80 g kg^{-1} DM) and 220 g kg^{-1} DM for the supplements. It was also noted that use of mixed rations resulted to higher TDMI of 4.5, 4.4 and 4.2 percent of live weight for goats in T3, T2 and T4 compared to only 3.0 percent for goats fed exclusively on the basal diet (T1) which means that the mixed rations provided a higher intake of digestible nutrients. It could also be associated with the fact that since mixing of different browse foliage may also have a positive associative effect on the digestibility or intake of the mixture and the elicited associative effect may consequently alter production performance of small ruminants (Niderkorn & Baumont, 2009).

The nutritional synergies between equal proportions of Calliandra and Vetch (50% CC; 50% CV) in T3 shows the highest TDMI, CP1 and OM and also had the lowest NDF content amongst the treatment diets, while T2 which comprised of 75% CC; 25% CV gained the highest live weight and ADG. This could be associated to the presence of the higher *Calliandra calothyrsus* proportion hence the presence of condensed tannins which bind proteins making them less degradable in the rumen but available for intestinal digestion and absorption (by-pass protein) thus improving nutrient utilization and therefore better production performance.

5.3 Growth performance

The ADG of goats supplemented with Calliandra (60.9 g/day) was in agreement with results reported by Wambui *et al.* (2006) of 57.1 g/day for goats offered urea-treated maize stover supplemented with Calliandra and ADG of weaner goats supplemented with 200 g/day of Calliandra but a depressed daily weight gain for those supplemented with 100 g/day and those on lucerne (Kinuthia *et al.,* 2007). Higher ADG have been reported in studies which considered the type of birth and the parity. Zahrdden (2008), reported ADG of 90.1 g/day and 87.0 g/day for single births and twin births, respectively. Higher parities were also reported to have higher ADG than the first parity.

The overall loss of weight by the un-supplemented goats was consistent with report by Wambui *et al.* (2006) and points to a conclusion made earlier by Sebsibe and Mathur (2000) that basal roughages alone are not sufficient to support optimal growth due to low levels of ingested protein and energy. Anya *et al.* (2011) also reported a loss of 1.48 kg live weight for West Africa Dwarf goat kids not supplemented, whereas the supplemented animals gained 1.1 kg live weight. A loss of 20 g/day was also reported in Zambia on goats fed low quality grass and a gain of 24 g/day when supplemented with 140 g/day of Calliandra leaf (Sebsibe & Mathur, 2000)

Supplementary feeding of dairy goats using mixed rations of CC and CV hay resulted in significantly improved and consistent growth rate in terms of total weight gain and ADG over the experimental period. The total weight gain of between 3.7 to 5.0 kg is comparable to that reported by Okello *et al*. (1996) where goats fed elephant grass and supplemented with cottonseed cake gained 5.6 kg, while Sultana *et al*. (2012) reported a total weight gain of 5.3 kg. The ADG of 66.4 to 89.9 g/day was consistent with that reported by Luo *et al*. (2004a) for a post-weaning growth rate of between 50-100 g/day for dairy goats. But the results differed with those reported in some past studies on goats, where lower ADG were noted. Pandy *et al*. (2013) reported an ADG of 56.8-64.6 g/day, 50 g/day reported by Niang *et al*. (1996), Sultana *et al*. (2012) reported 35.1 to 43.8 g/day, Njarui *et al*. (2003) reported 31.25 g/day while Ondiek *et al*. (2013) reported 15.7-20.3 g/day. The difference is mainly associated with the quality of both basal diet and the supplemental diets in terms of the CP content, NDF levels and the digestibility. The diets in the present study had higher CP for the basal diet (80 g kg^{-1} DM) and 220 g kg^{-1} DM for the supplements. It was also noted that use of mixed rations resulted to higher TDMI of 4.4, 4.5 and 4.2% of live weight for goats in T2, T3 and T4 compared to only 3.0% for goats fed exclusively on the basal diet (T1) which means that the mixed rations provided a higher intake of digestible nutrients. This was reflected in better growth performance for the supplemented goats compared to those on basal diet.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The present study led to the following conclusions:

i) Supplementation of Rhodes grass hay with dried *Calliandra calothyrsus* leaves and common Vetch (*Vicia sativa*) hay on growing dairy goats improved voluntary feed intake of basal diet of Rhodes grass hay, increased total live weight gain and average daily gain thus improving the overall production performance of the growing dairy goats.

ii) Supplementary feeding of growing dairy goats with equal proportions of Calliandra and Vetch (50%: 50%) and 7**5**%: 25%) fodder combinations significantly increased voluntary feed intake and average daily gain. Hence these mixed ration supplements on roughage based diets indicated promising results as protein supplements in feeding growing dairy goats suggesting that there could be a synergistic effect between the two legumes supplements as opposed to use of sole supplements.

6.2 Further Research

i. The possible effect of the anti-nutritive factors particularly the condensed tannins on nutrient utilization, thus, goat performance which was not done in the present study.

ii. A study should be conducted to determine the effect of supplementing the recommended fodder combinations in this study vis-à-vis commercial concentrates in the market on lactating dairy goats.

iii. A study should be conducted to further explore the synergistic effect between the two legume supplement and their potential benefit in improving animal production performance.

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APPENDICES

Appendix I: ANOVA Tables Experiment 1

i) Basal diet Intake

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

trt	intake LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	290.442500	11.155323	<.0001	1
2	360.810000	11.155323	<.0001	2
3	339.182500	11.155323	<.0001	3

Least Squares Means for Effect trt

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: intake

i/j	1	2	3
1		-4.46041	-3.0895
		0.0102	0.0487
2	4.460412		1.370911
	0.0102		0.4118
3	3.089501	-1.37091	
	0.0487	0.4118	

ii) Crude protein intake (CPI)

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

trt	intake LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	23.0925000	2.7784002	0.0002	1
2	66.9400000	2.7784002	<.0001	2
3	61.7500000	2.7784002	<.0001	3

Least Squares Means for Effect trt

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: intake

i/j	1	2	3
1		-11.1593	-9.83839
		<.0001	0.0002
2	11.15925		1.320862
	<.0001		0.4353
3	9.838388	-1.32086	
	0.0002	0.4353	

iii) Dry matter intake (DMI) for supplements

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

trt	intake LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	0.000000	8.492820	1.0000	1
2	166.442500	8.492820	<.0001	2
3	153.132500	8.492820	<.0001	3

Least Squares Means for Effect trt

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: intake

i/j	1	2	3
1		-13.8579	-12.7497
		<.0001	<.0001
2	13.8579		1.108182
	<.0001		0.5439
3	12.74971	-1.10818	
	<.0001	0.5439	

iv) Total Dry Matter Intake (TDMI)

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

trt	intake LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	290.442500	23.469053	<.0001	1
2	527.252500	23.469053	<.0001	2
3	471.110000	23.469053	<.0001	3

Least Squares Means for Effect trt

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: intake

i/j	1	2	3
1		-7.13493	-5.44339
		0.0009	0.0038
2	7.134926		1.691536
	0.0009		0.2830
3	5.44339	-1.69154	
	0.0038	0.2830	

v) Initial live weight of experimental units (weaned male dairy goats)

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

trt	dgain LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	11.4500000	0.2871072	<.0001	1
2	12.5500000	0.2871072	<.0001	2
3	12.1750000	0.2871072	<.0001	3

Least Squares Means for Effect trt

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: dgain

i/j	1	2	3
1		-2.70915	-1.78558
		0.0783	0.2522
2	2.709153		0.923575
	0.0783		0.6466
3	1.785578	-0.92357	
	0.2522	0.6466	

v) Final live weight gain of the dairy goats

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

trt	dgain LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	10.3625000	0.5491787	<.0001	1
2	15.9625000	0.5491787	<.0001	2
3	14.6875000	0.5491787	<.0001	3

Least Squares Means for Effect trt
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: dgain

i/j	1	2	3
1		-7.2104	-5.56875
		0.0009	0.0034
2	7.2104		1.641654
	0.0009		0.3006
3	5.568746	-1.64165	
	0.0034	0.3006	

vi) Total live weight change of dairy goats

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

trt	dgain LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	-1.08750000	0.52493386	0.0837	1
2	3.41250000	0.52493386	0.0006	2
3	2.86250000	0.52493386	0.0016	3

```
              Least Squares Means for Effect trt
           t for H0: LSMean(i)=LSMean(j) / Pr > |t|

                  Dependent Variable: dgain

        i/j              1             2             3

           1                     -6.06168      -5.32081
                                   0.0022        0.0043
           2      6.061679                     0.740872
                    0.0022                       0.7498
           3      5.320807      -0.74087
                    0.0043        0.7498
```

vii) Average daily gain

```
                       The GLM Procedure
                  Least Squares Means
        Adjustment for Multiple Comparisons: Tukey

                                  Standard                   LSMEAN
 trt      dgain LSMEAN               Error    Pr > |t|       Number

 1         -19.4150000       9.3747000      0.0838            1
 2          60.9375000       9.3747000      0.0006            2
 3          51.1150000       9.3747000      0.0016            3


              Least Squares Means for Effect trt
           t for H0: LSMean(i)=LSMean(j) / Pr > |t|

                  Dependent Variable: dgain

        i/j              1             2             3

           1                     -6.06076      -5.31988
                                   0.0022        0.0043
           2      6.060759                     0.740883
                    0.0022                       0.7498
           3      5.319876      -0.74088
                    0.0043        0.7498
```

Appendix II-ANOVA Tables Experiment 2

i) Basal diet Intake

The GLM Procedure

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

trt	intake LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	424.045333	30.079157	<.0001	1
2	584.237333	30.079157	<.0001	2
3	617.218333	30.079157	<.0001	3
4	551.934667	30.079157	<.0001	4

Least Squares Means for Effect trt
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: intake

i/j	1	2	3	4
1		-3.76583	-4.54115	-3.00645
		0.0354	0.0154	0.0854
2	3.765825		-0.77532	0.759377
	0.0354		0.8630	0.8697
3	4.541149	0.775324		1.534701
	0.0154	0.8630		0.4750
4	3.006448	-0.75938	-1.5347	
	0.0854	0.8697	0.4750	

ii) Crude protein intake (CPI)

The GLM Procedure

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

trt	intake LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	33.7116667	3.6474501	<.0001	1
2	74.0200000	3.6474501	<.0001	2
3	76.1520000	3.6474501	<.0001	3
4	68.3036667	3.6474501	<.0001	4

Least Squares Means for Effect trt
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: intake

i/j	1	2	3	4
1		-7.81431	-8.22762	-6.70612
		0.0010	0.0007	0.0022
2	7.814307		-0.41332	1.108187
	0.0010		0.9742	0.6982
3	8.227624	0.413317		1.521504
	0.0007	0.9742		0.4814
4	6.70612	-1.10819	-1.5215	
	0.0022	0.6982	0.4814	

iii) Dry matter intake (DMI) for supplements

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

trt	intake LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	-0.000000	12.306587	1.0000	1
2	191.855000	12.306587	<.0001	2
3	199.253333	12.306587	<.0001	3
4	177.802000	12.306587	<.0001	4

Least Squares Means for Effect trt
t for H0: LSMean(i)=LSMean(j) / Pr > |t|
Dependent Variable: intake

i/j	1	2	3	4
1		-11.0235	-11.4486	-10.2161
		0.0001	0.0001	0.0002
2	11.02352		-0.42509	0.807451
	0.0001		0.9720	0.8490
3	11.44862	0.42509		1.232542
	0.0001	0.9720		0.6311
4	10.21607	-0.80745	-1.23254	
	0.0002	0.8490	0.6311	

iv) Total Dry Matter Intake (TDMI)

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

trt	intake LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	424.045333	38.328874	<.0001	1
2	776.092333	38.328874	<.0001	2
3	816.471667	38.328874	<.0001	3
4	729.736667	38.328874	<.0001	4

Least Squares Means for Effect trt
t for H0: LSMean(i)=LSMean(j) / Pr > |t|
Dependent Variable: intake

i/j	1	2	3	4
1		-6.49471	-7.23964	-5.63952
		0.0026	0.0015	0.0054
2	6.494707		-0.74493	0.855188
	0.0026		0.8757	0.8272
3	7.239642	0.744935		1.600123
	0.0015	0.8757		0.4440
4	5.639519	-0.85519	-1.60012	
	0.0054	0.8272	0.4440	

vi) Total live weight gain of dairy goats

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

trt	dgain LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	0.60000000	0.58367054	0.3436	1
2	5.03333333	0.58367054	0.0001	2
3	4.26666667	0.58367054	0.0003	3
4	3.71666667	0.58367054	0.0007	4

Least Squares Means for Effect trt
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: dgain

i/j	1	2	3	4
1		-5.37091	-4.4421	-3.77579
		0.0069	0.0171	0.0350
2	5.370907		0.928803	1.595119
	0.0069		0.7916	0.4463
3	4.442103	-0.9288		0.666316
	0.0171	0.7916		0.9060
4	3.775788	-1.59512	-0.66632	
	0.0350	0.4463	0.9060	

Appendix III-Research Permit

THIS IS TO CERTIFY THAT:
MS. VIRGINIAH WANJIKU NGUNJIRI
of EGERTON, 1791-20100 Nakuru,has been permitted to conduct research in *Nakuru County*

on the topic: *EVALUATION OF PERFOMANCE OF GROWING DAIRY GOAT FED RHODES GRASS HAY, SUPPLEMENTED WITH DRIED CALLIANDRA LEAVES AND VETCH HAY*

for the period ending:
27th May,2020

Permit No : NACOSTI/P/19/90322/29935
Date Of Issue : 29th May,2019
Fee Recieved :Ksh 1000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

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Appendix IV: Publication In Journals

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RESEARCH ARTICLE OPEN ACCESS

EFFECT OF SUPPLEMENTING RHODES GRASS HAY WITH DRIED CALLIANDRA LEAVES AND COMMON VETCH HAY ON THE PERFORMANCE OF GROWING DAIRY GOAT CROSSES IN KENYA

V W Ngunjiri[1], P K Migwi[2], A Y Guliye[2] and N K Kibitok[2]

[1]Ministry of Agriculture, Livestock and Fisheries, P. O. Box 1791-20100 Nakuru, Kenya

[2]Department of Animal Science, Egerton University, P.O. Box 536- 20115 Njoro, Kenya

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*Corresponding author: V W Ngunjiri,.

ABSTRACT

A study was conducted to determine the effect of supplementing basal Rhodes grass hay with dried Calliandra leaves and common Vetch hay on growing dairy goats on voluntary feed intake and growth rate under a confined feeding system. A total of twelve weaned male Toggenburg crosses aged between 3 and 4 months were randomly allocated to 3 dietary treatments in a randomized complete block design. T1: Rhodes grass hay as the control, T2: 30% Calliandra + Basal diet, T3: 30% Vetch + Basal diet. The initial 10 days were allowed for adaptation to the diets and data collected for 8 weeks. The result of this study showed that live weight gain and average daily gain for supplemented goats was significantly different ($p<0.05$) for the supplemented goats compared to those fed on the control diet which gained 3.4 Kg and 2.9 Kg and average daily gain of 60.9 and 51.1 g/day for goats supplemented with Calliandra and Vetch respectively. The un-supplemented goats lost 1.09 Kg and had a negative daily gain. This study suggests that the Toggenburg crosses performed better when dried Calliandra leaves and common vetch hay were used as protein supplements on basal Rhodes grass hay.

Citation: ***V W Ngunjiri, P K Migwi, A Y Guliye and N K Kibitok.*** "Effect of supplementing rhodes grass hay with dried calliandra leaves and common