EFFECTS OF *PROSOPIS JULIFLORA* SEEDPOD MEAL SUPPLEMENT ON WEIGHT GAIN OF WEANER GALLA GOATS

By

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN RANGE MANAGEMENT IN DEPARTMENT OF LAND RESOURCE MANGEMENT AND AGRICULTURAL TECHNOLOGY, FACULTY OF AGRICULTURE, UNIVERSITY OF NAIROBI

JULY 2010

DECLARATION

I hereby declare that this thesis is my own original work and has not been presented for examination for a degree in any other university.

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ACKNOWLEDGEMENT

The success of this work was possible with the support of many people. I thank my supervisors Dr. R. Kinuthia Ngugi and Dr. Raphael. G. Wahome for their guidance and counsel during the entire period of training.

Special thanks go to Association of African universities (AAU) for granting me small grants for theses and dissertations that made me finish my research on time. Kenya Forestry Research Institute (KEFRI) for their funding of my research under Kenya agricultural Productivity Project (KAPP). The Kenya Agricultural Research Institute (KARI)-Marigat research centre for their support during my field studies and allowing me use their goats for the study.

To the staff of KARI-Marigat research centre, Mr. Josephat Chengole Mulindo, Mr. David Changwony, Mr. Duyu, Mr. Kimeto, Mr. Sammy, and Mr. Lang'at for providing me with the necessary support during my research in the field. The staff of KEFRI-Marigat research centre, Mr. Albert Luvanda, Mr. Peter Koech and Mr. Joel for their continued support during the study. To Mr. Dickens Ondigo and Mr. Edward Mulongo of the Department of LARMAT, Anne, Kinuthia and Karanja of Animal Production department for their assistance in lab analysis. I am also giving great thanks to Mr. John Maina for taking care of my experimental goats for the entire period. To all those mentioned and the many others who have not been mentioned, I say thank you and may God bless you all. .

ABSTRACT

This study was conducted to determine the effect of increasing amounts of *Prosopis juliflora* seedpod meal on the growth rate of weaner Galla goats. The overall aim of this study was to assess the feasibility of incorporating *Prosopis* seedpods into a typical dryland livestock production system. The study further sought to evaluate the economic viability of supplementing goats with *Prosopis* seed pods and establish the optimum supplementation level for improved performance.

The experiment involved 20 weaner Galla goats of similar age (6 months) and weights (11-14 kg) which were randomly assigned to four treatments of five weaners each. The treatments were T_1 No *Prosopis* (control treatment), T_2 (100 g /goat /day *Prosopis)*, T_3 (200 g /goat /day *Prosopis)*, and T_4 (400g /goat /day *Prosopis)*. Supplementation involved providing the goats with their respective portions of *Prosopis* seedpod meal in the morning before the grass hay was offered. The animals were weighed on weekly basis and the average weight gains calculated as the difference between that weeks' weight and the previous week's weight divided by five. The experiment lasted for 70 days. Overall, all the treatment groups exhibited higher average weekly weight gains than T_1 (control) throughout the experimental period. However, for the first 3 weeks, these differences were not statistically significant ($P<0.05$). From the fifth week on wards, however, the differences in growth rates were statistically significant ($P<0.05$). Overall, treatment T_3 exhibited highest total weight gain (3.96kg), followed by T_4 (2.70kg). Group T_1 lost weight by the end of the experiment (-0.009kgs). The cost benefit analysis indicated that it is profitable to supplement the goats with 200g/goat/day, which was the most cost effective with a benefit cost ratio (BCR) of 1.50. T_2 was also cost effective, but at a lower level (RBC=1.47). Treatment T_4 was not cost effective BCR (0.57). It is therefore recommended that supplementation at optimum level of *Prosopis* seedpods increases growth rates.

CHAPTER ONE

INTRODUCTION

1.0 Study Background

Trees and shrubs world-over have provided many benefits to man and his animals throughout the ages. Their leaves, flowers, pods and tender twigs (browse) have from time immemorial been an important source of wildlife and livestock feed. In many arid and semi-arid lands, this component is sometimes the only source of forage for these animals. Le Houérou (1978) pointed out that nearly one third of the world's land surface is natural grazing land and to varying degrees the shrub-tree component is a crucial source of animal feed. In the same document, analyzing data from various world locations, Le Houerou (1978) found a high dependence of rangeland grazing animals on trees and shrubs to satisfy their protein requirements, especially during the dry seasons. He concluded that, without these plants to complement other forage plants, the entire livestock production system would be jeopardized.

The foregoing situation is most likely going to be amplified further by the unfolding climate change phenomenon. Already, these plants are under serious threat, especially in the Sahel region, owing to increased periodic droughts and fast growing human and animal populations, leading to overexploitation. Other contributing factors include the emerging trend where more nomadic or transhumant communities are settling down to sedentary livelihoods resulting in increased pressure on these plants through expansion of cultivated areas and disappearance of fallows from cultivated areas.

In general, although trees and shrubs are the most visible plant life forms in arid lands, they have been neglected in almost all spheres of scientific research (McKell, 1974) and land management policies (Le Houérou, 1972). Motivated by a desire to increase livestock forage, numerous research efforts have been concentrated on methods of shrub eradication (Cook, 1958) or control (Scifres *et al.,* 1973). The magnitude of these efforts have inclined many students, research workers and land managers towards the myopic view that most, if not all, shrubs are of low-value and only by converting shrub lands to grasslands, can a productive grazing system be created. This view grossly overlooks the crucial role of trees and shrubs to, not only provide forage, but also 'even-out' the rampant nutrient supply deficits between the dry (dormant) and wet seasons. This prejudiced view towards ligneous plants in general may be attributed to the low appreciation of the tremendous value that they offer to mankind, inadequate knowledge of their biology and potential responsiveness to management. An international symposium on the biology and utilization of wild land shrubs (McKell *et al.,* 1972) was a good attempted to correct this bias, but there was need for follow-up effort.

Despite the past and current 'injustices' to trees and shrubs, it is obvious that they are a crucial component of all natural grazing systems throughout the world. In fact, it is inconceivable to visualize natural grazing lands devoid of these plants. Unlike grasses and forbs, ligneous plants, especially the evergreen types, provide livestock with fresh (green) forage during the dry season which is more nutritious than the 'dead' (dry) herbage. They serve as rich sources of proteins, vitamins, energy and minerals at a time when the preferred grasses and forbs are either not available or unable to provide these nutrients. With no supplementation, browse represents at least 20% of livestock diets during the dry season in the Sudano-Sahelian zone. Livestock keepers have from time immemorial utilized these plants to make up for nutritional shortfalls that occur during the dry seasons. From a strictly pastoral point of view, without this vegetation component, there would be no pastoralism as we know it today. The herd structure would be different as browsers like goats and camels, which survive and thrive in the driest parts, would be missing. Healthy management of tree-shrub ecosystems, aimed at maintaining the balance between browse and grass cover as well as trees and shrubs is therefore celestial obligation.

While it is apparent that ligneous plants have generally not received the research attention they deserve, man has relentlessly continued to utilize them. Over the ages, he has discovered practices that foster their utilization – sustainable or unsustainable. For instance, their utilization by livestock has been restricted to seasons when re-growth ability is not destroyed. On the other hand, lopping of branches, which is a common dry-season practice among pastoralists, is done on a rotational basis to allow time for regeneration and return of vigour. This is achieved through herding of livestock to prevent overuse of certain plants. There is also the practice of harvesting the pods from leguminous plants in the dry lands for storage and use as livestock feed during the dry seasons when little or no other forage is available.

1.1 The research problem

Prosopis juliflora (Sw.) DC, here after referred to as *Prosopis*, is an evergreen tree native to South America, Central America and the Caribbean. It was first introduced in Kenya in 1973 for the rehabilitation of quarries in Mombasa (Choge *et al.*, 2002). Later it was introduced to the semi-arid districts of Baringo, Tana River and Turkana districts in the early 1980s (Anderson, 2005). The tree has been reported by the local communities to be aggressive and hence competitive advantage and outgrows the native tree species, resulting in loss of the important plant species that were reliable sources of livestock forage. There are also cases of invasion and allelopathic properties in areas where it was introduced. Some members of the local communities have sued the government seeking compensation for general damages arising from some injuries on their goats which they attribute to consumption of *Prosopis* such as loss of teeth. The Invasive Species Specialist Group of the IUCN, (2004), rated it as one of the world's top 100 least wanted plant species.

Despite the foregoing controversies, *Prosopis* has proved to be a promising tree/shrub in the arid and semi-arid areas, which are characterized by low (<100mm) and erratic rainfall. *Prosopis* is widely distributed in the arid and semi arid areas of Kenya (about 600,000 ha). Pasiecznik, (1999) reported that *Prosopis* has invaded, and continues to invade, millions of hectares of rangeland in South Africa, East Africa, Australia and coastal Asia. It plays a critical role in providing livestock feed during the dry seasons. The tree also provides many other services and products such as charcoal, fuel wood, timber for furniture, construction material, soil stabilization, nitrogen fixation, reclaiming saline soils, bee forage and honey, and human food, among others.

The overall aim of this study was therefore, to assess the feasibility of incorporating *Prosopis* seedpods into a typical dryland livestock production system. Specifically, the study sought to determine the effect of increasing amounts of *Prosopis* seedpods on the growth rate of weaner Galla goats. This study further seeks to contribute to the inherent problem of inability of natural rangeland grazing systems' to supply adequate high quality livestock forage throughout the year to support acceptable livestock growth rates or, at least, minimize weight losses. There has been a problem of fluctuations in forage supply in the dry and wet seasons in the rangelands. In the latter seasons, there is surplus forage and animals are able to meet their nutritional requirements and hence gain weight. This is followed by dry seasons during which animals experience malnutrition from the poor quality and inadequate forage. In this study, we argue that prudent integration of the locally available fodder trees and shrubs into the grazing systems, through, for instance, stocking of the rangelands with the appropriate kinds and/or classes of livestock, at the right time, can go a long way towards evening out the forage quality and quantity fluctuations. However, this is only feasible when there is adequate knowledge about the growth habits of the trees and shrubs, the amount of forage they produce and the quality of that forage. On the other hand, knowledge of the kinds of animals best adapted to the grazing land is required.

1.2 Broad objective

To contribute to the improvement of livestock production in the arid and semi-arid zones of east Africa through strategic integration of *Prosopis* seedpods in the livestock production systems.

Specific objective

1. To determine the optimum substitution level of ground *Prosopis* seed pod meal in weaner Galla goat diets.
2. To determine the effect of increasing levels of *Prosopis* seedpod meal on dry matter intake and *in vivo* digestibility of weaner Galla goat diets.
3. To determine the effect of increasing levels of *Prosopis* seedpod meal on the average daily live weight gain of weaner Galla goats.
4. To determine the cost-benefit ratio of feeding *Prosopis* seedpod meal to increase the productivity of goats.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Supply of adequate quantity and quality of feed for livestock has been a major challenge throughout the world. Consequently, forage production has been the theme of many studies throughout the world, particularly in the dry tropics where this problem is rampant. The constraint of feed supply has led to low livestock productivity in most developing countries. Considering the vast arid and semi arid lands that form most of the rangelands in the tropics, the goats are one of the most adapted livestock species in these areas owing to their adaptive capacity to these environments. The range goats that are managed under semi-arid climatic conditions mostly rely on a variety of native forages to meet their nutritional requirements. However, these animals face great variability in supply of forage and nutrients throughout the year (Juarez *et al*., 2004). Despite this constraint in the same areas, trees and shrubs are the prominent sources of forage for range ruminants (Bhatta *et al.,* 2004) and are mostly utilized as protein supplements in the arid and semi arid lands (Makkar, 2003). This study therefore is geared towards assessing the effectiveness and benefits of supplementing goats with *Prosopis* seedpod. The literature reviewed here focuses on improvement of livestock production in the arid and semi-arid zones through strategic integration of locally available feed resources such as *Prosopis*.

2.2 Distribution and uses of *Prosopis juliflora* (Sw.) DC in Kenya

Prosopis juliflora (Sw.) DC (Meskit, Mesquite Americans) is an evergreen tree, a native of South and Central America; and the Caribbean. It produces a variety of valuable goods and services including construction materials, charcoal, soil conservation and rehabilitation of degraded and saline soils. *Prosopis* was first introduced in Africa in 1822 in Senegal, followed by South Africa in 1880 and Egypt in 1900. *Prosopis juliflora* and *Prosopis pallida* were introduced to Kenya in 1973 for the rehabilitation of limestone mines in Mombasa. It was later introduced to the semi-arid districts of Baringo, Tana River and Turkana districts in the early 1980s to provide ground cover (biomass) in areas that had none. It would also provide wood for domestic use, and generally improve the environment for human habitation (Choge *et al.*, 2002). Currently, the districts with the greatest *Prosopis* populations are Garissa, Wajir, Mandera, Baringo, Turkana, Taita Taveta and Tana River. *Prosopis* has a high potential for providing quality forage to livestock in the semi arid areas of Kenya owing to its high nutritive value of the pods and leaves all the year round.

2.3 *Prosopis juliflora* as a source of forage for livestock

Lack of adequate and high quality forage is one of a major constraint to livestock production in the tropics (FAO, 1981), particularly the lack of adequate protein during the dry season. According to Mahgoub *et al*., 2005), *Prosopis* pods contained 127 g/kg CP, 254 g/kg CF, 26 g/kg EE and 48 g/kg ash. This shows that Meskit (common name for *Prosopis juliflora* in America) pods are ideal livestock feed compared to most available feed resources. It is relatively high in protein content and hence if incorporated into animal feeds, it will improve growth and productivity of livestock. Other studies have also shown that, *Prosopis* pods are a good source of protein and energy, with 12-14% crude protein content (Wood *et al.*, 2001a).

Prosopis retains all its leaves during the dry season, showing even satisfactory output levels of the seedpods. Therefore, the introduction of this species will partly offset fodder scarcity during the dry season, thereby improving livestock raising prospects in the dry areas where this plant species is abundant, and the pods can be collected at low costs (Primo *et al.*, 1984). Digestibility of the forages is related to their protein content and this relationship is of exponential nature (Kinuthia, 1982).This implies that, *Prosopis* that has high protein content, will have an increase in feed intake and digestibility by livestock. *Prosopis* seedpods, which are traditionally cultivated in the semi-arid northeast, have characteristically high carbohydrate content and reasonable protein value. These pods lend themselves better to feeding livestock when ground and turned into flour; thus increases the digestibility and acceptability to animals. Andersson, (1978) pointed out that pod crushing and drying does not influence voluntary intake by animals.

Prosopis seedpods are sweet, nutritious and have low concentration of tannins and other unpalatable chemicals and has moderate to high digestibility (Mooney *et al*., 2001), and therefore it plays a big role as a nutritious feed to animals. In natural grazing lands where *Prosopis* seedpods are abundant, livestock consume the seedpods voluntarily during grazing and browsing, and in many species the seedpods contain a sweet, dry yellow pulp and the seeds contained in the pods are high in protein 34-39% (Gutteridge and Shelton, 1998).

The seedpods can sustain livestock in dry seasons when little other feed is available. However, when pods of some species (*Prosopis pallida* and *Prosopis glandulosa*) are fed as an exclusive diet for long periods, livestock, particularly cattle, can become malnourished and show ill-thrift symptoms. Thus, it is recommended that livestock consuming *Prosopis* pods should also have access to other feeds to balance their diet (Gutteridge and Shelton, 1998). *Prosopis* seedpods are low in tannin content and hence the anti-nutritive capacity is low when fed to animals. It is also reported that Leguminous browse plants, such as *Proposis* species, generally contain higher levels of crude protein than other shrub families (Wilson, 1969), and are often good sources of forage reserves.

2.4 The role of *Prosopis* browse in livestock supplementation

Supplementation is a management tool used by livestock producers to supply nutrients during periods of deficiency. The major nutrients required by animals are proteins and energy. Also minerals like phosphorus, calcium, iron, and selenium are important for animal performance and growth. When there is deficiency of these nutrients, animals perform poorly – they lose weight, have low fertility and low morbidity. Supplementary feeding should provide animals with nutrients in amounts and combinations that the pasture is not providing at the time (Anderson, 1978). Supplemental feeding on the range is an economic question to be decided upon by balancing the cost against additional production (Korir, 2008). Supplementation is profitable when it increases the reproductive rate of breeding herds, reduces death losses. And more so, when locally available, low-cost forage resources can be used in the place of more costly commercial feeds (Primo *et al.*, 1984).

Previous studies have shown that *Prosopis* has the potential of being used as livestock supplement, though much needs to be done to find out the actual optimum level of supplementation for the different regions and species of *Prosopis*. Research studies by Mahgoub *et al*. (2004) on *Prosopis* supplementation showed that during the experiment, animals were in excellent condition throughout the trial. They found that feeding *Prosopis* pods to Omani sheep did not affect their health although it contained *Prosopis* pods, which was reported to cause health problems in goats by other studies.

Roughages, especially standing hay have a low crude protein content and poor digestibility (Karue, 1974, and Momanyi, 1993). This results in reduced intake of digestible nutrients and consequently poor animal performance. Thus, integrating *Prosopis pods* in the feeding programme can ameliorate this situation by improving the quality and intake of roughages due to its high protein content. It is reported that a sporadic period of nutrient deficiency causes mortality surges in livestock especially small ruminants (Momanyi, 1993), which, in turn, reduce the farmers' profits and increase in production costs. Supplementation to poor quality roughage increases the intake of useful nutrients (Anderson, 1978) which, in turn, supports higher levels of animal performance.

A study by Silva *et al*. (1983) involving progressive replacement of wheat bran with *Prosopis* pods in proportions of 25%, 75% and 100% in rations of bovines and showed better dry matter, crude protein, digestible protein, and total digestible nutrient conversions between 25% and 100% pod content. Primo *et al.* (1984) investigated dietary interactions between *Opuntia ficus indica,* elephant grass hay (*Pennisetum purpureum Schum*) and complemented with 500 g of *Prosopis* seedpods per goat/day during the dry season. They found that all combinations furnished the necessary nutrients for goat maintenance. Corroborating these findings, studies by Lima *et al.* (1984) tested several combinations of *Opuntia* and mature elephant grass hay on confined ovine's, complemented with 500 g of *Prosopis* pods per animal/day, and found that any one of the combinations tested can be recommended for ovine supplementation during the dry season.

Studies by Mahgoub *et al.* (2005) on the supplementation of Omani goats with *Prosopis* seedpods concluded that *Prosopis* pods at 200 g/kg of diet maximized feed intake, body weight gain and feed conversion. Studies with *Prosopis* in Brazil showed that *Prosopis* seedpod meal could replace up to 600 g/kg of wheat flour in rations of lactating cows and that dry matter intake (DMI), weight gain and milk production increased with increasing proportions of the seedpod flour (Mahgoub, 2005). In beef cattle diets, the studies showed that it was possible to totally replace wheat flour with ground *Prosopis* seedpods. Study in Mexico where sorghum flour was replaced with *Prosopis* seedpod flour up to 450 g/kg, showed significant increase in body weight gain (BWG) in sheep. A study in Brazil has shown that replacement of sugarcane molasses with *Prosopis* pods at 0, 150, 300, 450 and 600 g/kg of total ration was most effective in terms of body weight gain at between 300 and 450 g/kg levels (Mahgoub, 2005).

In conclusion, it is evident from the few studied cited here that *Prosopis* and particularly the seeds pods can be strategically utilized as supplementary feed for livestock especially the small ruminants (sheep and goats), by sheer coincidence, in Kenya, *Prosopis* preponderance in the arid and semi-arid areas, such as Baringo, Garissa, Moyale, Isiolo, Turkana, and Marsabit where the production of small ruminants is a key economic activity.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

This feeding study was conducted at Kenya Agricultural Research Institute, Marigat, Perkerra centre, in Baringo district, Kenya. The district was selected because of its high abundance of *Prosopis* and the fact that goat production is a key economic activity.

3.2 Experimental animals, supplements and protocol

Twenty weaner Galla goats of similar age (6 months), sex (male) and weight (11-14 kg) were randomly assigned to the four treatments resulting in five animals per treatment. The experimental animals were housed in individual pens of approximately 2.5m wide and 3.5m long. The pens were constructed from *Prosopis* poles. Each cage had a feed and water trough.

Prior to bringing all the animals to the pens, they were injected with antibiotic (Adamisine) to minimize stress-induced ailments such as pneumonia. They were also dewormed and sprayed against ectoparasites. The latter was repeated every fortnight and the former after every 4 weeks during the entire study period.

The experimental goats were allowed 14 days to adapt to the cages. During this period, they were fed on mixed-species hay obtained locally. They were introduced to their respective treatment diets during the last three days of the adaptation period. The experimental duration was 70 days, and the animals were weighed every week.

The supplemental diets comprised *Prosopis* seedpod flour and grass hay. The pods were harvested at the ripening stage and stored under cool dry conditions. They were then sun-dried for three days and then milled and stored. The pods were ground in a 2-3mm hammer mill.

Plate 1: Research goats feeding on *Prosopis* seedpod meal

The treatments were, i) T_1 (Control) - Hay only), ii) T_2 (100g of *Prosopis* pod meal per goat per day), iii) T_3 (200g of *Prosopis* pod meal per goat per day) and iv) T_4 (400g of *Prosopis* pod meal per goat per day). Hay, water and minerals were provided *ad labium.* Feeding was done twice per day, at 0800 and 1500hrs. In the morning the animals were offered their respective supplements and 1kg of hay. In the afternoon, they were only offered hay and the amounts were adjusted according their previous day's intake.

3.2 Determination of hay intake and digestibility of the diets

All the experimental animals were weighed every week at 07.00 hrs after overnight fast and the weights recorded according by treatment groups. Average Daily Gains (ADG) of the animals were later calculated and recorded as the total weight gained at the end of experiment divided by experimental days. The amount of hay offered to each animal was recorded daily. Before fresh hay was offered, the feed troughs were cleaned out and orts (refuse) weighed and recorded. The orts were then thoroughly mixed, a sub-sample taken for analysis and the rest discarded. The amount of hay consumed was then determined as the difference between the amount offered and the refuse. When a new batch of hay was brought in, a sample was taken for chemical analysis later. *Prosopis* seedpod meal sample was also taken for chemical analysis each time a new batch was acquired.

Digestibility of the diets was determined using three of the animals from each treatment group. These were selected at random and placed in standard individual crates for metabolic studies. They were allowed seven days to adjust to the crates and seven days of sample collection. All the feces produced by each animal was collected, weighed and a representative sample (about 10% of daily output) taken. The fecal samples were sun-dried and packed in plastic bags for chemical analysis later. In addition, all the urine produced by each animal each day (24 hours) was measured volumetrically. The urine was collected into a plastic bucket fitted under the metabolic crates. Approximately 15mls of 1M H_2SO_4 was added to each trough to reduce nitrogen loss through volatization. A sub-sample {15% (v/v)} of the daily output was taken and bulked across the days. The samples were stored in a freezer set at -4^{o} C for later nitrogen content analysis.

3.3 Body condition scoring procedure

At the end of study period, all the experimental animals in each treatment were assessed for body condition and assigned a score. The body condition scoring method used in this study was that by Spahr (2009) which uses a 1-5 ranking, where, 1 represents an animal in bad body condition (very thin) and 5 represents an animal in prime body condition (well fleshed). Table 1 presents the body condition scoring indexes used in this method. An average body condition score was calculated for each treatment group as the sum of the scores of each animal in the group, divided by 5.

Table 1: Body condition scoring criteria

Score	Spinous process	Rib cage	Loin eye
BCS 1 Very thin	Easy to see and feel, sharp	Easy to feel and can feel under	No fat covering
BCS 2 Thin	Easy to feel, but smooth	Smooth, slightly rounded, need to use slight pressure to feel	Smooth, even fat cover
BCS 3 Good Condition	Smooth and rounded	Smooth, even feel	Smooth, even fat cover
BCS 4 Fat	Can feel with firm pressure, no points can be felt	Individual ribs cannot be felt, but can still feel indent between ribs	Thick fat
BCS 5 Obese	Smooth, no individual vertebra can be felt	Individual ribs cannot be felt. No separation of ribs felt	Thick fat covering, may be lumpy and "jiggly"

Source: Spahr (2009)

3.4 Cost-benefit analysis of the supplementation programme

During the experimental period, all the costs associated with the supplementation were recorded. These costs included; purchase of the seedpods, cost of drying and milling the seedpods; and the cost of variable inputs (feeding, dewormers and sprays). The benefits used were the live weight gained at the end of supplementation period. The prevailing market prices in the study area for (2009), price per (Kg) live weight (KES 80/=, price from KARI-Marigat) were used in calculating benefits. The benefits and costs of this supplementation were spread over a period of 4 years.

3.5 Chemical analysis

The feed and faecal samples were oven dried at 60^{o}C for 24 hrs and then ground through a 1mm Wiley mill in preparation for chemical analysis. DM, OM, ash and N were determined using the proximate method (AOAC, 1990), while ADF and NDF were determined using the procedures of Goering and Van Soest (1982). Mineral content was determined using the AOAC (1990) procedures. Faecal N and DM content were determined on wet samples using proximate method (AOAC, 1990. The urine samples were thawed and pooled according to treatment groups, thoroughly mixed and analyzed for nitrogen following the Macro-Kjedahl method (AOAC, 1990).

3.6 Data analyses

The experimental data on growth performance and feed intakes were analyzed by one-way analysis of variance (ANOVA) (Steel and Torrie, 1980). Where treatment differences were statistically significant, mean separation tests were conducted using Duncan's New Multiple Range Test (Steel and Torrie, 1980) at 5% level of significance.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Chemical composition of hay and pods

Table 2 below presents the average chemical composition of the *Prosopis* seedpod meal (supplementary feed) and the hay (basal feed). Overall, the hay had higher in dry and organic matter, but lower in digestibility than the seedpod meal. Notable also is the fact that the pod meal had about three times the amount of crude protein. The two feed components were similar in terms of neutral and acid detergent fiber. However, the hay had about three times more lignin than the pod meal. The *Prosopis* seedpod meal was slightly higher in Ca, P and K than the grass hay. Mg, Fe, Zn, Cu and Na were almost similar in the two feed components. Both feed components were notably very high in K, but Ca and P, were well above the daily requirements for sheep and goats.

Table 2: The average chemical composition (DM) of *P.juliflora* pod meal and hay

Chemical Component	*Prosopis* seed pods	Hay
DM (%)	88.4 ± 0.3	99.4 ± 0.2
OM (%)	83.2 ± 2.8	90.0 ± 4.6
CP (%)	18.5 ± 0.3	6.1 ± 0.3
ASH (%)	5.2 ± 0.7	9.4 ± 0.7
NDF (%)	51.8 ± 4.2	59.0 ± 5.9
ADF (%)	29.8 ± 0.1	26.8 ± 3.5
ADL (%)	3.2 ± 0.4	8.1 ± 0.5
Ca (%)	0.5 ± 0.1	0.3 ± 0.1
P (%)	0.2 ± 0.1	0.1 ± 0.1
K (%)	0.9 ± 0.1	0.6 ± 0.3
Mg (PPM)	760 ± 3.0	917 ± 5.5
Fe (PPM)	99 ± 2.8	219 ± 4.0
Zn (PPM)	1279 ± 6.4	1365 ± 29.9
Cu (PPM)	40 ± 4.0	38 ± 2.0
Na (PPM)	51 ± 3.0	56 ± 3.0

At 6%, the hay CP content was below the minimum (7%) requirement for optimal microbial activity in the rumen (Abdulrazak *et al.*, 2006). Low nitrogen content in feeds is associated with low intake and digestibility of the feeds which, in turn, results in reduction in availability and assimilation of nutrients by the animal and, ultimately, low animal performance. There is therefore need to supply adequate nitrogen to ruminants feeding on poor quality forages. This improves the utilization of poorly digestible feeds. Ammonia enhances the microbial population growth and increases the digestibility of feeds. When the microbial population is enhanced, there is an increased rumen fermentation and hence nutrients availability to the animals.

Lignin reduce the microbial activity in the feeds ingested by the animal and hence the digestibility of the feed. The hay used was poor in digestibility due to high lignin compared to *Prosopis,* and hence resulted to poor performance of the goats. The minerals that animals need most are P, Ca and Mg (Kebede, 2002). They also need small amounts of other minerals, including: Fe, I, Co and Cu. This was present in *Prosopis* pods and hay in adequate amounts that could show good performance and no signs of deficiencies. The young growing, pregnant and lactating animals need adequate amount of minerals (Juarez *et al*, 2004). The mineral contents for *Prosopis* used in our study were similar to those reported by Abdulrazak *et al*, (2006). They concluded that the CP and mineral concentration of *Prosopis* forage were satisfactorily high and warrant consideration of its use as supplement to low quality feed.

4.2 Feed intake (DM), digestibility, animal weight gains and feed conversion efficiency

The dry matter intake (Kgd^{-1}) and live weight gains (Kgd^{-1}) of the weaner goats are presented in table 3. Treatment group T_1 (no *Prosopis* pods) had significant ($P<0.05$) effect on dry matter intakes in the four treatments. This group was not supplemented and had to take more DM to meet its nutritional requirements but due to the poor quality hay that was used, the weight gains were low. However, treatment T_2 and T_3 had about the same dry matter intakes that were not significantly different ($P<0.05$), despite the differences in treatments.

In vivo dry matter digestibility of *Prosopis* meal was higher than that of hay, 74.5 and 56.8% respectively. This can be attributed to the high CP that was present in *Prosopis*.

Table 3: Dry matter intake of hay, weight gains and Feed conversion ratio

	Total hay intake (Kg)	Hay intake (Kgd^{1})	Total live weight gain (Kg)	ADWG (Kg)	Feed conversion ratio+
T_1	24.000^{a}	0.352^{a}	-0.630^{a}	-0.009^{a}	-38.095
T_2	17.200^{b}	0.252^{b}	2.250^{b}	0.034^{b}	7.644
T_3	17.500^{b}	0.257^{b}	3.960^{c}	0.061^{c}	4.419
T_4	13.350^{c}	0.196^{c}	2.700^{d}	0.031^{d}	4.944

Treatment means followed by same superscript within columns are not significantly different ($P<0.05$).

Animals in T_3 exhibited the highest total hay intake ($0.26Kgd^{-1}$) as well as the highest average daily weight gain ($0.061Kgd^{-1}$. These findings are comparable to those of Mahgoub (2004) who reported that goats fed 20% Ghaf (*Prosopis cineraria)* had higher feed intakes than those on 30% Ghaf. These high intakes of basal diet (hay) can be attributed to the fact that, the Ghaf provided adequate energy: protein ratio, which not only increased the essential nutrients to maintain optimal rumen activity, but was also more rapidly degraded in the rumen. Ørskov and Dolberg, (1984) reported that supplement should be highly digestible materials containing cellulose and/or hemicelluloses, which increase feed intakes and digestibility.

Animals in $T_{4,}$ on the other hand, exhibited lower hay intake than the animals in all the other treatments (0.196Kg/day) which closely tallied with the findings of Mahgoub *et al*. (2004), where sheep fed on increasing amounts of Ghaf at 0%, 15%, 30% and 45%, demonstrated a sudden drop in feed intake when the amount of Ghaf approached 45%. Horton *et al.* (1993) also observed a drop in feed intake in Omani sheep when the Ghaf level approached 29%. The reduction in feed intakes exhibited by animals on high proportions of *Prosopis* pods may be largely attributed to the increase in tannin and other phenolic compounds in the diet. Presence of these compounds has been associated with reduced rumen microbial activity. Also, despite *Prosopis* seedpod meal contribution of the essential nutrients, increased proportion might have taken much longer to be broken down in the rumen and hence the lower intakes of the basal diet (hay). Ingested fibre material must be broken down by rumination, microbial fermentation or both to produce particles which are small enough to pass through the reticulo-omasal orifice Blaxter *et al*., (1956); this should be at a reasonable rate of passage through the gastro-intestinal tract for nutrient absorption and increased intakes of feed. If the rate of passage is low, then the intakes are low, and this can be attributed to our observation for T_4.

Feed conversion ratio (FCR) is a gross measure of feed utilization efficiency and is most often used as a tool to evaluate groups of growing and finishing animals to determine costs of production and break-even prices in production operations. Animals that will convert at a high rate (lower FCR) are more preferred to those with lower ratio. In this study, T_3 animals exhibited the highest feed conversion rate (FCR=4.4) while T_1 had the lowest conversion rate (FCR = -38.1). Diets with a low FCR are considered to be more economical in animal production. In addition; identifying cattle that have lower intakes that can optimize performance can be valuable in environments that have lower quality and/or quantity of feed resources like the ASALs. Feed conversion ratio is moderately heritable (Crews, 2005) and cow/calf producers who have access to these data can potentially use this information as a marketing tool to promote the sale of their feeder calves. These low FCRs observed in this study can be attributed to the fact that *Prosopis* contributed the fermentable energy to the rumen in the form of available cellulose and hemicelluloses which stimulate fibre digestion and hence nutrient released for growth (Silva and Ørskov, 1985).

4.3 Average weekly weight gains

The average weekly weight gains of the goats under different treatments for the 10-week feeding period are presented in the table 4. Overall, all treatment groups exhibited higher average weight gains than the control group. However, the differences were not statistically different ($P<0.05$) during the first three weeks. However, between the 5th to the 10th week, all the supplemented groups exhibited significantly higher growth rates than the control ($P<0.05$). T_3 had the highest weight gain (61gd^{-1}) followed by T_2 and T_4 (34gd^{1}) and 31gd^{-1} respectively. T_1 lost weight.

Table 4: Mean weekly live weight gains (Kg) of weaner Galla goats on varying amounts of *Prosopis* seedpod meal

Treatment	Week 2	3	4	5	6	7	8	9	10
T_1	-0.20^a	-0.20^a	-0.16^a	-0.11^a	0.16^a	0.28^a	0.22^a	0.34^a	0.32^a
T_2	0.14^b	0.20^c	0.06^b	0.24^b	0.18^a	0.38^c	0.36^b	0.37^a	0.36^b
T_3	0.18^c	0.30^d	0.20^c	0.26^b	0.42^b	0.47^d	0.62^c	0.64^c	0.86^d
T_4	0.13^b	0.08^b	0.07^b	0.24^b	0.38^b	0.32^b	0.56^d	0.52^b	0.44^c

Treatment means in the same column with different superscript are significantly different (P<0.05)

These superior performances exhibited by the supplemented goats can be largely attributed to the high CP content of the seedpod meal. The results here demonstrate a direct relationship between the CP content and animal performance. The results also show a positive relationship between the dietary CP content, hay intake, and animal performance. The hay intake increased with increase in CP content which, in turn, improved the growth rate of the goats. The findings of this study were consistent with those of Mahgoub *et al*. (2005) who reported that goats fed 20% Meskit (*P.juliflora)* pods had the highest weight gains whereas those fed 30% had the lowest feed intake. They also reported that the goats fed rations with Rhodes grass hay as a major constituent of the diet, had lower feed intake than those fed 10 and 20% Meskit pods, possibly due to relatively higher fiber content.

In this study, the T_4 treatment group depicted the lowest weight gain rate but started losing weight from the 8^{th} week. The weight loss was associated with lower feed intake which, in turn was attributed to the high proportion of *Prosopis* in the diet. As indicated above, the latter may have depressed feed intake due to reduction in palatability associated with the tannins and other phenolic compounds. Mahgoub *et al*. (2005) also observed loss of weight in goats fed on diets with 30% Meskit.

Figure 3 presents the mean of weekly weight gains throughout the study period. The T_3 treatment group had the highest mean weight gain rate and hence the best performance. This can be attributed to a combination of high CP and total feed intake. As expected, T_1 had the lowest weekly weight gain. This is attributed to the low total feed intake as well as low CP intake due to lack of supplementation.

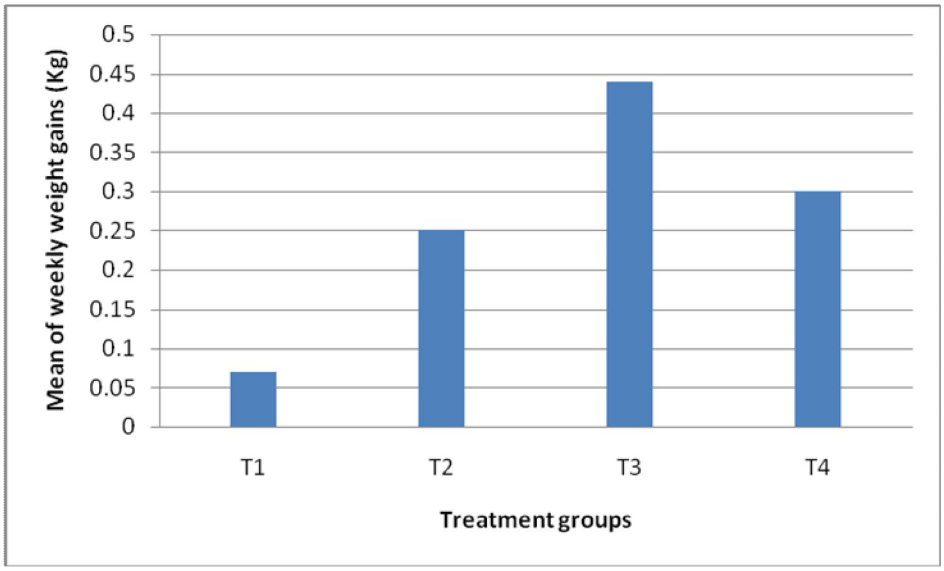

Figure 1.The mean of weekly weight gains for different treatments

4.4 Nitrogen Balance

Table 5 presents the nitrogen balance status of the animals relative to the different levels of *Prosopis* seedpod meal in their diets. Fecal N and Urinary N were significantly different ($P<0.05$) among all the treatment groups. The total nitrogen intake increased with the increase in the quantity of the *Prosopis* seedpod meal in the diets. Treatment T_4 with highest amount of *Prosopis* pod meal and hence, the highest dietary N content ($7.2gd^{-1}$), showed the highest level of fecal nitrogen (FN) loss ($3.2gd^{-1}$) and highest total loss which was significant ($P<0.05$) than the other treatments. The T_1 (control) which was on hay only, and hence the lowest dietary N ($3.2gd^{-1}$), demonstrated the lowest N retention ($0.6gd^{-1}$) and low total N loss. This outcome is similar to that of Freeman *et al.* (2009), who found that N retention was lower in un-supplemented goats than those that were supplemented.

Treatment group T_3 had the highest nitrogen retention rate $4.5gd^{-1}$, followed by T_4 and T_2 with 3.4 and $2.3gd^{-1}$ respectively. There was significant differences in nitrogen retention in both the treatment groups ($P<0.05$). However, the total nitrogen loss was significantly ($P<0.05$) higher in the supplemented groups than the control group (T_1).

Table 5: Nitrogen budget of goats supplemented with various levels of *Prosopis* pod meal

Diets	T_1	T_2	T_3	T_4
Ingested N gd^{-1}	3.2^a	5.4^b	6.7^c	7.2^d
Faecal N loss (gd^{-1})	1.7^a	1.9^b	1.2^c	3.2^d
Urinary N gd^{-1}	0.9^a	1.2^b	1.0^c	0.6^d
Total N loss gd^{-1}	2.6^a	4.1^b	4.5^c	5.9^d
Retained N gd^{-1}	0.6^a	2.3^b	4.5^c	3.4^d
N retained (%)	18.8^a	42.6^b	67.2^c	47.2^b

Treatment means followed by same superscript within rows are not significantly different ($P<0.05$)

The apparent increases in loss of N through the feces and reduced N retention with increase in *Prosopis* level were attributed to increased tannin intakes with the increase in amount of seed pod meal. Most browses are known to contain relatively high quantities of tannins which are known to depress browse intake by decreasing its palatability and/or reducing the digestibility of proteins associated with them (Swain, 1979). Tannins have a propensity to form insoluble complexes with proteins which reduces the digestibility of forages by inhibiting digestive enzymes as well as causing a decrease in protein availability to the animal (McLeod, 1974). Working with blackbush (*Coleogyne ramosissima*), Provenza and Malechek (1984) found evidence that tannins may have a greater effect on palatability than digestibility which can explain the phenomenon observed in T_4 which exhibited lower feed intakes, and lower N retention than T_3, despite the fact that it received the highest intake of N.

In terms of relative N retention vis-avis N intake, all the supplemented groups depicted significant differences ($P<0.05$) in the quantities of N the animals retained compared to T_1 (control). T_3 had the highest N retention (67.2%), Hence, it was the best performing group in terms of weight gains and body condition, followed by T_4 and T_2 (47.2) and (42.6) respectively, which were not significantly different ($P<0.05$). T_1 (control) had the lowest N retention (18.8), consequently, the poor performance and weight loss at the end of experiment.

The superior N retention rate depicted by T_3 can be attributed to efficiency in the utilization of CP ingested, due to adequate amounts of hay intake that provided energy needed, which boosted the microbial population, which, in turn, increased the digestive activity to the ingesta. A study by Shukla *et al.,* (1984), on Kakrei bullocks, offered a concentrate ration incorporating 0%, 15%, 30% and 45% levels of *Prosopis* pods, reported an increase in live weight gain and positive balances of N, Ca and P up to 30% *Prosopis* content. However, 40% *Prosopis* exhibited the lowest intake of hay, despite the high CP intake. Most probably the digestion may have been impaired at this level of *Prosopis* integration due to the low N retention rate. Shukla *et al*., (1984) also observed that at 45% level of pod feeding, there was a slight negative N and P balance, and reduced live weight gain compared to animals at 30% *Prosopis* seed pod level. As expected, T_1 had low N retention due to poor quality hay (low CP content). Freeman *et al*. (2008) also observed low N retention in goats supplemented with secondary protein nutrients (SDN) at increasing proportion and attributed this to decreasing ruminal protein degradability.

The amount of cell wall contents, which is determined by the neutral detergent fiber (NDF), and the degree of lignifications (ADL) are the most important factors determining forage quality and digestibility (Van Soest, 1982). High levels of these compounds depress digestibility of forage (Barton *et al.* 1976). Lignin, which was present in the supplement diets, is a structural material and has been reported to be one of the components most highly associated with reduced digestibility (Van Soest, 1982). This can partially explain the lower digestibility and N retention observed in T_4 treatment group. Wilson (1977) conjectured that lignin may have some inhibiting activities of cellulases as well as have an antibacterial function.

4.5 Average body Condition scores according to treatments

Table 6 below presents the average body score indices of goats according to the treatments. The control treatment goats had the lowest body condition score at the end of the experiment. They were the lowest in live weight and most emaciate. It was easy to feel their ribs. T_3 goats, on the other hand, had the best body condition score. They were smooth and well fleshed. T_2 and T_4 had the same body condition scores of 2. They were neither too thin nor as well fleshed as the T3. Body condition score index is a tool used to adjust feeding of animals. Management decisions involving livestock nutrition are important to achieve the best body condition at calving and later post calving reproductive success. BCS helps in matching feedstuff quality with the nutritional requirements of the animals at different reproductive stage for maximum profits. However, this should be done gradually since ruminant animals are sensitive and any change greatly affects their rumen micro-organisms (Spahr, 2009). This can result in problems such as diarrhoea. Supplementary feeding can be adjusted up or down by using the body condition scores.

Table 6: Average body condition score indices of goats according to the treatment groups

Treatment	Body Score
T_1	1
T_2	2
T_3	3
T_4	2

A study by Zahraddeen *et al*. (2009) on the factors influencing milk yield of local goats under semi-intensive systems in Sudano-savannah ecological zone of Nigeria, found that, body condition scores significantly influenced milk yield. The latter increased with increase in the doe's body condition score. This study shows that it is a parameter that is important in monitoring productivity of goats. Body condition scoring can be easily used to monitor nutritional regimes of a cowherd (Manuel *et al.,* 2000). This includes a supplementation interventions aimed at improving livestock nutrition. Adjusting the nutritional regime to obtain desired body condition at different stages of production is necessary to enhance production efficiency (Manuel *et al*, 2000).

4.6 Cost-benefit analysis of the experiment

Table 7 presents the cost-benefit ratios associated with the four treatments of this study. T_3 had the highest CBR followed by T_1 and T_4, respectively. Treatment T_4 had the lowest CBR; this is because it had the highest cost of supplementation with low returns in terms of weight gains. The CBR should be 1 in a break even situation, below this, as in the observation with $T_{4,}$ is un-economical and does not give return to supplementation investment. From this study, T_3 was the most cost effective treatment followed by $T_{2.}$ They have a ratio greater than one, which implies that it pays to supplement at the levels between 100 and 200g/goat/day *Prosopis* pods. Studies by Mesfin and Ledin (2004), comparing the cost benefit ratios of feeding cows on urea treated teff, barley straw-based and hay-based diets showed that the latter were the most expensive diet, followed by the urea-treated teff straw diets. Furthermore, the hay-based diets had the lowest net return; whereas the urea treated teff straw had the highest net return. CBA helps in decision making in any production.

Table 7: Cost-benefit analysis of supplementation with *Prosopis* seedpods flour

Treatment	Expected benefits (KES)	Expected costs (KES)	BCR
T_1	0	0	0
T_2	5,040.00	3,430.80	1.47
T_3	15,444.00	10,692.40	1.50
T_4	7,776.00	13,723.20	0.57

KES-Kenyan shillings

Supplements are fed to improve the production efficiency and meet the production targets to optimize gross margins. From this study, growth performance results showed there were significant differences ($P<0.05$) between supplemented goats and the un-supplemented. This gives the reason for cost benefit analysis of the different levels of supplementation that aids in making appropriate decision for supplementation intervention.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Prosopis being a native tree that grows in most ASALs of Kenya, it has good properties that enables it grow even in areas with rainfall far much below 100mm. It has a competitive advantage over many tree species, with a high capability of providing livestock with forage during the dry seasons, since it remains green throughout the year. The tree has also many other uses besides forage, such as fuel wood, building material, charcoal, restoration of degraded areas among others. The results of this study demonstrate that there is a benefit in utilizing the widely available *Prosopis* seedpods as a supplement for livestock feed. The seedpods contained high nutrient contents, having CP 18.5%, DM 88.4%, OM 83.2%, Ash 5.2%, ADF 29.8%, NDF 51.8%, and ADL 3.2%, with adequate amount of calcium, phosphorus, iron, magnesium, potassium, zinc and copper.

Supplementation of *Prosopis* at higher proportions negatively affects hay intakes in goats. This may be attributed to high nutrient content that meet the animal's requirements, or reduced palatability and low digestibility rates. The weight gains were improved on supplemented goats than the control, with high weight gains with inclusion of *Prosopis* up to 200g/goat/day. While at higher levels of *Prosopis* (400g/goat/day), the goats lost weight.

Feed conversion efficiency is improved with inclusion of *Prosopis* seedpod flour at 200g/goat/day. The un-supplemented group had a poor feed conversion ratio of negative.

The cost benefit analysis of supplementation is economical between 100 and 200g/goat/day *Prosopis*; this is so because of higher weight gains, resulting to higher benefits and lower variable cost incurred. A higher level of supplementation with *Prosopis* leads to increased variable costs and poor weight gains hence un- economical.

This study demonstrates that *Prosopis* supplementation gives good weight gains, increased intakes, digestibility and feed conversion efficiency. This implies that there is great opportunity in utilizing *Prosopis* as livestock supplement, given that it has no competition with humans for food like many conventional supplements.

Based on the findings of this study, the following recommendations were found to be important:-

- That livestock farmers should be advised to supplement their goats with *Prosopis* seedpod meal particularly during the dry season.
- That inclusion of *Prosopis* seedpods in commercial feed supplements to be used to improve productivity of ruminant livestock in the country and reduce competition between humans and livestock in food resource allocation.
- There is need for further studies on *Prosopis* supplementation in different livestock species and for longer experimental periods.
- The *Prosopis* pods used for supplementation be grinded to reduce chances of propagation and increase its digestibility for goats.

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