THE EFFECT OF WATERING FREQUENCY ON FEED INTAKE, DIGESTIBILITY AND BODY WEIGHT GAIN OF THE *NGANDA* SHEEP IN EASTERN UGANDA

BY

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DECLARATION

I hereby declare that this thesis is my original work and that it has not been presented for a ward of a degree in any other University.

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DEDICATION

This work is dedicated to my daughter Edith who missed me too much during the period I was away.

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ABSTRACT

This study was conducted at Kyerima village, Kitimbwa Subcounty, Mukono district, eastern Uganda to determine the effect of watering frequency on water consumption, feed intake, feed digestibility and body weight gain of local *Nganda* sheep. Sixteen, four-months old male sheep, of approximately 16 kg each were purchased locally and housed in individual pens in the same barn. The animals were randomly assigned to the following four treatments (watering frequencies): (1) *Ad-libitum* water supply – water available at all times (T_1); (2) Once after 24 hour (T_2) – animals watered for 30 minutes every 24 hours; (3) Once after 48 hours (T_3) – animals watered for 30 minutes after 48 hours. (4) Once after 72 hours(T_4) – animals watered for 30 minutes after 72 hours.

The animals were subjected to a preliminary period of one month during which they were fed on the experimental diet. The results showed that watering frequency had a significant effect ($P<0.05$) on the amount of water consumed, dry matter consumed, dry matter digestibility and body weight gain of the sheep. The sheep in treatment T_1 consumed the greatest amount of water and feed followed by those under T_2, T_3 and T_4, respectively. There was a linear positive relationship between water and dry matter intake (R^2 = 0.94). Likewise, there was a linear positive relationship between water intake and dry matter digestibility (R^2 = 0.86). The results showed a significant effect ($P < 0.05$) of watering frequency on the body weight gain. There was also a linear positive relationship between watering frequency and the body weight gain (R= 0.94). T_1 sheep gained the highest weight followed by those under T_2, T_3 andT_4, respectively. The results of this study strongly suggest that intermittent watering inversely impacts the sheep in terms of the amount of water and feed they consume, their feed digestibility and ultimately their performance. Hence, free access to water is the ideal situation in which the sheep performance is highest. However, since free access to water

is not possible in arid and semi-arid lands, our results suggest that sheep should be watered at least once daily for better performance.

CHAPTER ONE

INTRODUCTION

Water is an absolute necessity for all kinds and classes of livestock and lack of access to an ample supply is a serious limiting factor to production in many parts of the tropics (Devendra and Burns, 1970). Animals require water for at least two different purposes, namely (1) as an essential nutrient and component of the body, and (2) agent for reducing heat load through conductive or evaporative cooling. Presence of adequate water in body tissues is an essential pre-requisite to the normal maintenance of life and water is a fundamental constituent of living cells. It is intimately concerned with the transportation of nutrients and excretory matter between the digestive system, cells of different body tissues, and the excretory organs. Apart from specific production needs, water is constantly needed to balance the continuous losses from the kidneys, the intestinal tract, the skin and the lungs (French, 1956).

Total water intake by species, breeds within species and individuals animals within breeds varies within very wide limits, but all domestic ruminants usually require access to free water (Payne, 1966). Available literature on water and feed consumption by livestock indicates that the two are closely related. Feed intake is quantitatively related to water intake (Utley et al., 1970). Moderate restriction to water intake leads to reduced feed intake and animal productivity.

With more severe restriction, weight loss is rapid as the body dehydrates (Church and Pond, 1978). Accurate and comprehensive dataset on the amounts of water that different kinds and/or classes of animals require in different eco-climatic zones, and under different environmental and body conditions is far from complete. This is more so with free-ranging animals in the arid and semi-arid areas. That big differences exist between amounts of water consumed by animals under unrestricted supply, and that consumed under restricted supply, is common knowledge (Chesworth, 1992). Even when water is always available to livestock, it is necessary to know both the average daily water requirement and the period of maximum demand. The water requirements of an animal vary according to the type of animal and the ecological conditions. Extreme conditions are found in eco-climatic zone VI in northern Kenya (Pratt and Gwynne, 1977) where livestock are normally watered every third day.

By virtue of water's participation in the essential physiological functions of the body, it is probably more critical to animal life than energy, protein, minerals or vitamins. For instance, whereas starving animals may lose nearly all their glycogen and fat reserves, half of their body protein and about 40 percent of their body weight and still survive, loss of only 10 percent of body water causes serious disorders and further loss may quickly lead to death (French, 1956). Therefore, more animals die due to lack of water than starvation yet only scanty attention has been given to it in terms of research.

Easy access to water can improve the productivity of individual livestock in several ways. When water is provided closer to where livestock are grazing, they either water more frequently or spend less time and energy walking to water. Time saved walking to the watering points can be spent on grazing. More frequent watering tends to increase productivity by increasing the animal's appetite and if feed is available, the amount eaten increases (Sandford, 1983). However, when no extra feed is available and the animal's appetite has been stimulated by provision of extra water, this may have negative rather than positive effects on production. This is because reduction of an animal's water intake causes a corresponding reduction in the animal's minimum requirement for energy for long-term survival (fasting metabolic rate). Conversely, raising water intake raises this minimum energy requirement leaving less energy for conversion into useful products under restricted diet (Sandford, 1983). Furthermore, easier access to water tends to be associated with a slightly lower efficiency of food use, measured in terms of the proportion of dry matter eaten and digested.

One of the major problems of grazing livestock in many parts of the tropics is the seasonal effect of climate on herbage dry matter production (Webster and Wilson, 1980). For a considerable part of the year, in the more arid tropical areas, grazing consists of mainly low quality standing herbage. On the other hand, the water content of certain grasses during the wet season may be so high that grazing animals will obtain all or almost all their requirements through their diets. The demand for water, therefore, increases as the dry season progresses, with the peak corresponding with the period of highest ambient temperatures. The water content and nutritional value of available forages tend to be very low during this period and the surface water resources are at their lowest levels (Devendra and Burns, 1970).

Under the foregoing conditions, the indigenous East African livestock often graze as far as twenty kilometres from the nearest watering point in the dry season. Many animals die annually through either over drinking or excessive exertion when running to the watering (Pratt and Gwynne, 1977). Therefore, information on the water requirements of livestock and their ability to withstand its scarcity is of practical management importance to livestock producers (Kahsay, 1998). Pastoralists need to know how often they should water their livestock so as to increase growth rates and milk production. The long- and short-term effects of water restriction under arid and semi arid environments, for the various kinds/classes of livestock need to be well documented (Wilson and Brigstocke, 1981). The general objective of this study was, therefore, to determine the effect of watering frequency on the nutrition and body weight gains of the local *Nganda* sheep in Mukono district, Uganda.

The specific objectives were to determine the effect of watering frequency on:

(i) daily water intake

(ii) daily feed intake

(iii) Feed digestibility

(iv) Body weight gain

The working hypothesis was that watering frequency had no effect on either water intake, feed intake, feed digestibility or body weight gain.

CHAPTER TWO

LITERATURE REVIEW

Water sources and requirements

In almost all animal tissues the largest constituent is water (Chesworth, 1992). About three-quarters of a carcass (excluding the gut contents) of a juvenile animal is water and the remainder is composed of protein. As an animal matures, the proportion of protein in the carcass remains relatively constant, but there is a large increase in the amount of fat. The gut of an animal usually has even higher amount of water. Animals must, therefore have a supply of water to maintain this high proportion of water in the tissue.

Animals maintain their body water through drinking water, food eaten, metabolic water, stored body water, water liberated from polymerization reactions such as condensation of amino acids to peptides and preformed water associated with body tissues which are catabolized during periods of negative energy balance. The most important source is the water that animal consumes directly. Water obtained from feeds consumed varies from feed to feed depending on the moisture content, which can vary from as low as 5% in dry feeds to as high as 90% in root crops, lush pastures or other succulent feeds (Hailay, 1998).

While water derived from dry feeds may be insignificant compared to the total water intake, water obtained from succulent feeds can supply all the water needs of the animal. The feed moisture content at which no free water is necessary is high for water dependent ruminants such as cattle, intermediate for small ruminants and low for desert adopted ruminants, such as camels.

In addition to the water derived from feeds, oxidation of organic nutrients during metabolic processes in the body leads to the formation of water from the hydrogen present. On average, fats, carbohydrates and proteins yield 1.07, 0.57 and 0.40 ml of water per gram of feed oxidized or an equivalent of 0.12, 0.14 and 0.10 litres of water per kcal of metabolizable energy derived from the oxidation of the respective nutrients (Hailay, 1998). Livestock vary greatly in their water requirements which determines how often they should be watered and the distance they can travel to water.

Factors governing water requirements

The body requirements for water are governed by many factors and are subject to wide variations in any particular kind of animal over short periods (Crowther, 1938). It reduces to a minimum during periods of fasting and reaches its maximum at the time of heavy production of watery products such as milk. Much water is required to balance that lost by excretion through lungs, skin, kidneys and intestines. These losses are highly variable depending on the diet and other factors.

Losses through the intestine as represented by the amount of water voided in the faeces vary with the animal species. Thus, sheep faeces are drier than those of cattle and there is strong evidence that tropical sheep breeds have different tolerances to both water stress and quality (Devendra and Mcleroy, 1982). Similarly, losses of water through urine, varies according to the forms in which the waste nitrogenous products are present. In mammals, the principal product is urea, which is soluble in water and toxic to the body tissues, if the concentration is too high. A mammal, therefore, requires large amounts of water to dilute the urea to a harmless concentration and remove it from the tissues and excrete it. The heavy loss of water as vapour in the breath of animals is obvious. This is greatly increased by physical activity and other factors, which speed up the rate of respiration.

Water requirements also depend on factors like body size, breed, environmental temperature, water temperature, salinity, relative humidity, wind velocity, rainfall, dry matter intake, physical condition of the animal, and the availability of drinking water (Wilson and Brigstocke, 1981). The nature and amount of food consumed markedly affect animal water intake. For example, high protein and fat diets are associated with higher water intake than those with low levels of these dietary components (Kahsay, 1998). Degree of salinity, as well as, the concentration of specific ions or a combination of ions, in some cases influences the water requirements of ruminants. The higher the proportion of minerals in a diet, the greater the excretion of urine and consequently the higher the water intake. Mittal and Ghosh (1986) reported 54% reductions in dry matter intake, 42% reduction in digestible energy and an apparent increase in digestibility of cell-wall constituents in water restricted sheep during summer.

Significant increases in urinary and faecal volumes result in decreases in total body water concentration, total plasma volume and extra and intra interstitial fluid volumes. When sheep are restricted to half their normal daily water requirements, primary water conservation mechanisms permit sheep to adapt to low water intake levels. Dry matter intake is considered to be the major factor affecting water intake. However, the pattern of water intake may change with the type of dry matter consumption during the day (Bass, 1982)

From the foregoing, it is clear that the water requirements of animals under field conditions vary widely with changing environmental conditions, even for the same class of animals and general recommendations, therefore, have very limited value.

However, with healthy animals, there are no deleterious effects from excessive consumption of water. Therefore, practical water needs are adequately met by making sure animals have the opportunity to consume the necessary amounts at frequent intervals. Although data on the economic effects of water quality on livestock performance, is scarce, logic indicates that farm water supplies, either surface or ground, should be protected against contamination from micro-organisms, harmful chemicals and other pollutants (Pfost and Fulhage, 2001). Substances that originate from livestock farms and often contaminate water supplies include nitrates, bacteria, organic materials and suspended solids. A high level of suspended solids and an objectionable taste, odour or colour in water can cause animals to drink less than they should.

Effects of water restriction to livestock production

Water restriction originates from the absence of surface water and scarcity of well systems. Consequently, it may not be practical or economical, at least during dry periods, to provide adequate water to livestock when they require it. This compels livestock owners to economise and conserve water use by livestock through watering at certain intervals rather than on a daily basis (Zewdu, 1999). The benefits of the practice include efficiency of water use, labour use and exploitation of more distant grazing (Hailay, 1998). Effects of water restriction on the animals result from interaction between the degree of water restriction and duration of the same (Toha *et al.* 1987).

In order to gauge the relative importance of different watering regimes, either to maintain production or water economy and survival, the water requirements of livestock and their response to various degrees of water deprivation should be investigated under normal field conditions. Under these conditions, at least, during the dry season in arid and semi-arid regions of the world, water is limited in availability and therefore it is not possible to have adequate supply for livestock. Hence animals face the challenge of maintaining a balanced water metabolism. Water deprivation (complete or partial) produces various physiological changes in ruminant animals. The reported responses to the various degrees of dehydration have been considerably variable, depending not only on the degree of water deprivation or restriction, but also on various environmental factors that affect water requirements (Hailay, 1998).

Effects of watering frequency on water intake

Water intake is linked to water availability (Chesworth, 1992) and animals will drink more water when they can get it. Water deprivation appears to reduce the total water intake of livestock after normal water supply is restored. Most studies indicate that the maximum amount of water that can be drunk at a ago, and the ability to compensate daily water loss vary with the degree of dehydration. This is mainly determined by the difference in the elapsed time between watering.

Animals differ markedly in their ability to withstand dehydration. Species with low water turnover can survive longer than those with higher water turnover. French (1956) showed that water deprivation for 48 and 72 hours at a time, reduced water intake of stall-fed *Bos indicus* cattle by 12% and 30.7%, respectively.

Clark and Quin (1949a) reported that when sheep were fed on a poor quality diet, deprivation of water for 72 and 96 hours, reduced water consumption by 63 and 54% respectively. Payne (1966) reported that in a two-year study in East Africa, with identical twin cattle, water deprivation for 48 and 72 hours reduced water intake by grazed *Bos indicus* cattle by 10% and 26%, respectively. In the second year, deprivation during the dry season did not reduce water intake to the same extent as during the first year. It was conjectured that cattle might have acquired some degree of acclimatisation.

The maximum amount of water an animal can drink at a given visit to a watering point varies with its degree of dehydration and the time it spends near the water (King, 1983). In many parts of East Africa, Classen (1977) found that indigenous zebu cattle drank about 23 litres when watered daily, 35 litres after a very long walk on a two-day watering regime and a maximum of 45 litres on a three-day watering regime. In a sheep study, Williamson and Payne (1978) found that water deprivation for 48 and 72 hours reduced total water intake by 10% and 26%, respectively.

The same authors recorded a maximum of 45 litres on a three-day watering regime with high risk of water intoxication and death. Watering intoxication occurs following ingestion of excessive quantities of water, especially if a great deal of salt has been lost due to severe exercise or high environmental temperatures (Kahsay, 1998). The water is rapidly absorbed into the blood stream, thus reducing the plasma osmotic pressure. This may be avoided in susceptible animals by initially allowing them access to limited amount of water, allowing them to rest for a while, and then allowing them access to all they can drink. In practice, both availability and access to water determines intake (Gatenby, 1986).

Umunna *et al* (1981) working with *Yankasa* sheep in northern Nigeria found a linear decrease in water intake as watering frequency increased from one to four days. When water is freely available, housed or yarded animals usually drink at frequent, short intervals imbibing small quantities at a time. More and Sahni (1981) reported that *Chokla* sheep on a 4-day watering regime were able to drink up to 37% of their dehydrated body weight within 2 to 3 minutes during summer. The same authors, while working with non-breeding ewes in an earlier study noted less total water intake on a 3-day than a 2-day watering cycle. Such responses could partly be accounted for by the shrinkage of the reticulo-rumen as a result of the adverse effects of water deprivation (Hailay, 1998). *Bedouin* goats of the Middle East desert were found to consume about 47% of their dehydrated body weight in 2 minutes following 4 days of water deprivation during summer (Brosh *et al.* 1983). The incremental water consumption by ruminants following water deprivation is an attempt to compensate the deficit accumulated during the deprivation period. In line with this, More and Sahni (1978) observed higher average daily water intake on alternate days. Webster and Wilson, (1980) recorded similar observations in non-breeding ewes where the value was higher on a 3-day than alternate or daily watering regimes during a monsoon.

Effects of watering frequency on feed intake

An animal's first response to water restriction is reduction in voluntary feed intake. Water requirements vary with the types of feed, indicating that the amount of water that is adequate for a particular diet could be insufficient for another. Further studies by Aganga, (1989) tested the effect of water restriction on feed metabolism. The studies reported that water intake significantly affected the feed intake by the sheep. The results confirmed a high dependency of feed intake (on dry matter basis) on water intake. However, feed management through variations in concentrate-to-roughage ratios, as well as processing methods also significantly influenced water intake, with water intake increasing with increase in the concentrate to roughage ratio.

Results of most research studies on water restriction indicate that feed intake generally decreases with the duration of water restriction (Toha *et al.* 1987). There seems to be a general consensus that water restriction in domestic ruminants leads to a decline in feed intake by cattle, sheep and goats (Musimba, 1986). Phillips (1960) studied the effect of water and feed restriction on Zebu and Hereford steers and he observed that water restriction led to a decline in feed consumption by both cattle breeds. Water intake dropped by 12% and 31% and feed intake by 6% and 8% when steers were watered once in 48 and 72 hours, respectively.

Work by Phillips (1960) indicated that the ratio between water intake and feed intake varied from 1.92 to 4.2 in Hereford steers and 1.47 to 3.35 in Zebu steers, depending on ambient temperatures. These data suggest that there may be no constant ratio between water and feed consumed. Devendra and Burns (1970) stated that water deprivation seriously affects the feeding capacity of the sheep.

Dry matter and water intake are strongly related in livestock. Water consumption has been considered to be a function of dry matter intake (Sekine and Asahida, 1987). Inadequate water supply reduces dry matter intake and the effect is more severe at higher ambient temperatures. Clark and Quin (1949a) concluded that when sheep were fed on good hay and provided with water twice a week, feed intake was reduced by 30%. In another study (Clark and Quin, 1949b) water restriction caused a rise in body temperature and hence loss of appetite. Devendra and Burns, (1970) found that dry matter and water intake by sheep were significantly correlated. Gordon (1965) showed that when housed sheep were not provided with drinking water for 96 hours their feed intake decreased by 46%.

Phillips (1960) and Payne (1966) have shown that, under the same environmental conditions, *Bos indicus* cattle do not reduce their feed intake to the same extent as *Bos taurus* cattle when deprived of drinking water. This ability of *B. indicus* cattle to maintain a reasonable feed intake in the face of water scarcity is probably one of the main advantages of keeping these types of animals in semi-arid tropical environments. Inadequate supplies of drinking water restrict dry matter intake and the higher the ambient temperature the more severe the decrease in dry matter intake (Payne, 1966). If at the same time, the animal is allowed insufficient time for grazing, which is a normal practice in many pastoral areas (Payne, 1966), its intake of nutrients may be inadequate. On the other hand, if the nutrient content of the available feed is low, which is common in almost all the semi-arid tropical regions, as the dry season advances, then voluntary dry matter intake will also decrease.

Few studies have been carried out to evaluate the physiological basis of the reduced feed intake as a result of water restriction (Musimba, 1986). Clark and Quin (1949b) suggested that water restriction in sheep caused an increase in body temperature, which, in turn, led to appetite depression. A more likely cause for reduced feed intake following water restriction may be its effect on rumen function. Phillips (1960) tentatively concluded that restriction of water intake usually resulted in the digesta being retained in the rumen and lower digestive tract for a longer time. Brosh *et al.* (1983) reported a drop in daily feed intake to one-half and one-third following 3 and 4 days of water deprivation, respectively. These results were comparable to those obtained when water was offered once every 4 days following 2 and 3 days restriction (Brosh *et al.* 1983).

Khan and Sasidharan (1978) also obtained a one-third reduction of feed intake after 4 days of water deprivation in the Indian desert goats. Ghosh *et al.* (1976) found that *Marwari* sheep ceased taking feed on the fourth day of water deprivation, with feed intake having dropped by about 90%. Similarly, in studies carried out in summer, Macfarlane *et al.* (1961) found that Merino sheep ceased to eat after 2 days of water deprivation. Likewise, in studies with sheep watered once in 5 days in a moderate warm environment, Gordon (1965), observed one-third and one-half reduction in feed intake on the third and fourth day of water deprivation, respectively. However, there was no appreciable impact of water restriction on feed intake during the first one to two days of water deprivation. Gordon (1965) and More and Sahni (1981) observed no significant change in feed intake between the watering day and the following day of water deprivation when water was offered to sheep once every 2 or 3 days during hot months. However, a significant reduction was observed on the second day on the latter watering frequency.

In line with the above findings, Wilson (1970) observed a reduction in feed intake by one-tenth and one-third in sheep watered once every 3 or 4 days, respectively. It was noted that on the day the sheep were watered, feed consumption rose again to the original level. Work by Little *et al.* (1975) with lactating cows receiving water *ad-libitum*, 87%, 73% and 60% of their *ad-libitum* intake, showed a decline in feed intake with increase in water deprivation. However, the reduction was only significant at the 60% water deprivation. Other studies by the same authors also showed a marked decrease in feed intake by cattle as a result of 40% reduction in normal water intake.

The decrease in feed intake resulting from water restriction was found to be relatively less in Zebu than in European cattle (Phillips, 1960) and in goats than in sheep at high temperature (More and Sahni, 1981). If adequate feed is available, water deprivation reduces productivity, but if inadequate feed is available, water deprivation, if not too prolonged can be advantageous to the animals, as it assists in conservation of nitrogen and possibly other food constituents in the body (Williamson and Payne, 1978).

Effects of watering frequency on feed digestibility

Workers in temperate and tropical countries have reported that water deprivation increases feed digestibility, and in particular, the digestibility of crude fibre (French, 1956 and Payne, 1966). There is evidence that the effects of water on digestibility may not be directly related to water deprivation, but as a result of reduced feed intake, Payne (1966) coupled with the effects of production of additional saliva. Because rumen fluid provides some of the water to meet water losses during the initial stages of dehydration (Macflarlane *et al.* 1961), water deprivation may be expected to affect rumen function. Gordon (1965) found that when housed sheep were deprived of water for 96 hours, rumination, expressed in terms of the number of boluses regurgitated, decreased by 34%.

Water intake is quantitatively related to feed intake and nutrient digestibility generally increases when feed intake decreases in response to restriction of water intake (Toha *et al.* 1987). Water restriction induced favourable response in nitrogen retention in the ruminant, presumably, by increasing protein digestibility and reducing urinary urea losses (Toha *et al.* 1987). It has also been reported by Blaxter *et al.* (1956) that digestibility of nutrients and particularly crude fibre is increased by water deprivation as a result of reduced feed intake.

Contrary to the above findings, Mehta and Ludri (1976) found no effect of restricted water intake on digestibility of dry matter, organic matter, acid detergent fibre, cellulose, crude protein, ether extracts and nitrogen free extracts. These results were contradictory to those of Balch *et al.* (1953), French (1956), Phillips (1960) and Thronton and Yates (1968) who reported increased feed digestibility, and in particular that of crude fibre in dairy cows and steers. Thornton and Yates (1968) showed that the increased dry matter digestibility associated with water restriction was largely related to decreased rate of passage of digesta. Balch *et al.* (1953) found a decrease in the rate of passage of digesta through the reticulo-rumen of water-restricted cattle. They suggested that drastic reduction in defecation and accumulation of dry matter in animals under water restriction caused elevated digestibility. Utley *et al.* (1970) noted that digestibility coefficients of water-restricted steers tended to be consistently higher, but it was difficult to determine if the increased apparent digestibility was due to reduced water intake or reduced feed intake. On the other hand, Huston *et al.* (1986) suggested that digestibility of diet in free-grazing animals is a product of a variety of factors including diet selection, fermentation rate and passage rate.

Effect of watering frequency body weight gains

Water intake is an intermittent activity, while its loss is continuous process. As a result, an animal is always faced with the problem of slow dehydration. After a long period of dehydration the animal will be depleted of both water and primary electrolytes.

Aganga (1989) in a trial to determine the influence of watering frequency on grazing sheep showed that intermittent watering caused weight loss in experimental animals during the dry season. Those on daily watering gained 66 g per day. During the rainy season, all animals gained weight in spite of the watering intervals imposed on them. This was associated with the high moisture content of the pasture (about 80 percent). The decrease observed in mean live-weight gain with increased water deprivation were consistent with the findings of Umunna *et al.* (1981) in their study on sheep deprived of water during the dry season. The animals on 72 hours and 96 hours watering intervals grew lean and staggered whenever they attempted to graze, the effect becoming more pronounced towards the end of the study. The skin was rough and dry and hair came off easily after 40 days. This observation agreed closely with that of Schoen (1968) who reported skin dehydration and hair loss in water-deprived East African goats. Water deprivation raised blood biochemical constituents significantly (Little *et al.* 1978). Water-deprived ewes showed signs of haemoconcentration. Aganga (1989) noted that protracted water deprivation appeared to impose a serious stress on the animals during the dry season. He also noted that variations in rectal temperatures were slight among animals on varying watering intervals and a decrease in urine output and production of dry faeces was observed in the water-deprived animals during the dry season. These animals appeared to drink in a compensatory fashion whenever they had access to the water. He further noted that water deprivation also significantly lowered the respiratory rate in sheep. Jaw movements were drastically reduced with long watering intervals, indicating that rumination was seriously impaired by water deprivation. The lactating ewes were the most significantly affected, with milk yield and growth rate being most severely affected. Ewes on a daily watering schedule produced the highest quantity of milk, while those on 72-hour watering programme produced less than 50 % milk.

The short-term effect of water deprivation on the live weight gain of ruminants can be dramatic (Payne, 1966), but this may be largely due to loss of body water. The long-term effects are not so well documented, but since water deprivation reduces feed intake, it might be expected to decrease live weight gain also. French (1955) stated that water deprivation for 48 hours reduced the live weight gain of cattle by 50%. Payne (1966), over a two-year experimental period, found that cattle intermittently deprived of drinking water weighed 14.9% less than their normally watered identical twins, although differences in live weight gains between the two groups were noticed during the first six months of the experiment.

The most noticeable effect of moderate water restriction is reduced feed intake and reduced productivity. With more severe restriction, weight loss is rapid, as the body dehydrates (Church and Pond, 1978). The dehydration is accompanied by increased excretion of nitrogen and electrolytes such as Na^+ and K^+. Water restriction causes even more severe effects during higher ambient temperatures. Animals vary greatly in the amount of dehydration they can withstand, with camels being able to withstand weight losses of 30 percent or more (Church and Pond, 1978). Most mammals cannot survive such severe dehydration. With moderate water restriction most animal species show some adaptation and can partially compensate for any water loss by reducing excretion

According to Gatenby (1986), water deprivation in a hot climate results in loss of body weight. A study by More and Sahni (1978) showed that three-month old lambs in Rajasthan, India watered once every two or three days, weighed approximately 19 kilograms, compared to 24 kilograms for the control group-watered every day. Taneja (1965) reported that when *Marwari* wethers in India were watered every two, three or four days for 12 days, their weight losses were 6%, 9% or 12% of their body weight, respectively. He concluded that it is safer to water sheep every three days instead of four days, as this allows them to maintain normal respiration rates and body temperatures. Umunna *et al.* (1981) in their experiment with *Yankasa* sheep in northern Nigeria found out that as watering frequency decreased from one to four days, food intake declined only slightly. However, there was a marked decrease in live weight gain as food conversion efficiency was low at the infrequent watering intervals. Church and Pond (1978) noted that with severe water restriction, weight loss was rapid as the body dehydrates. The dehydration is accompanied by increased excretion of sodium and electrolytes such as Na^+ and K^+. Webster and Wilson (1980) also noted that a major feature of water deprivation for ruminants is its effect on live weight gain, while the short-term effect is marked due to reduction in body water. Similarly, Umunna *et al.* (1981) working with sheep found that there was a marked decrease in live weight gain as watering frequency was increased from one to four days. Khan *et al.* (1978) found that after 4 days of absolute water deprivation, goats lost body weight at the rate of 1.5% per day, cattle at 8% per day, *Merino* sheep at 4—5% per day, and camels at 1% per day. Balch *et al.* (1953) also observed body weight losses in water-restricted cows. The reduction in body weight during water restriction may be due to less body water *per se* (Payne, 1966).

There was evidence from grazing trials that daily watering of lactating ewes caused a significant increase in body weight during the monsoon season, while those watered every 3 or 4 days did not show such pattern (More and Sahni, 1978). Brosh *et al.* (1983) found that the body mass of goats fed on a low quality diet was maintained constant when provided with water once every 4 days in contrast with a light, continuous loss of body mass in those provided with water once per day. These researchers concluded that infrequent drinking is not totally disadvantageous to ruminants faced with a low dietary protein. This concept was supported by King (1983), who on the basis of secondary data postulated that whenever the quality of the feed is low, water deprivation precipitated a "siege economy" in animals, whereas free access to water accelerates depletion of tissues. This provocative suggestion, however, has not been fully substantiated by many other experiments.

Bohra and Ghosh (1977) studying the response of *Marwari* sheep to the level of water intake recorded 21% body weight loss in 23 days at 50% water deprivation during summer with most of the body weight loss (90%) having occurred within the first 9 days. Under drought conditions, there is a cyclical weight loss in animals between watering sessions. This is caused by high water consumption on the day of watering. For example, camels may drink up to 140 litres of water when it is available. And this may increase the dehydrated weight of the camel by 25%.

CHAPTER THREE

MATERIALS AND METHODS

Description of study area

The study was conducted in Kyerima village, Kitimbwa subcounty, Ntenjeru County, Mukono district, Uganda. This is an agropastoral area within mid-eastern Uganda. It is classified as ecological zone III. The area lies 1000 and 1520 metres above sea level to the north and south, respectively. It also lies between Latitudes 1^0 38' N and 1^0 00' S and Longitudes 32^0 31' E and 33^0 26' E.

There are two main types of soils in Mukono district, namely, Ferralisols and Ferrisols. In the study area, the Ferralisols are dominant. These are soils formed where weathering and leaching processes have reached their final stages. The vegetation of the study area consists of wooded bushland dominated by *Acacia* spp. especially *Acacia mellifera, A. nilotica* and *A. nubica.* There are many associated trees and shrubs. The herbaceous layer mainly consists of *Themeda* and *Eragrostis* spp.

The agropastoral areas of Mukono district in mid-eastern Uganda experience severe water shortages, making human settlement very difficult and seriously affect livestock production. This area has two dry seasons, i.e. a long one, from December to March and a short one from June to July. During these months, water is hardly available and in drought years, many livestock die due to lack of water. The average number of wet days per year is 75 in this area compared to 144 in central Uganda. Temperatures are high with a mean maximum of 26.3^0C and a mean minimum of 15.1^0C. The highest temperature recorded during the study was 32.2^0C. The high temperatures increase evapo-transpiration rates, which further reduces water availability (Okedi, 1998).

Generally, rainfall in Kyerima is low and highly localised. The area receives a bimodal rainfall. The long rains normally come between March and June, while the short rains are expected between August and November. The mean annual rainfall varies between 750 and 1000mm. This total, however, gives little idea of the effectiveness of the rainfall. If the rainfall is too intense over a short period of time, much of it is lost as surface runoff. On the other hand if a few millimetres of rainfall are received on each day, most of this is lost as evaporation from the soil.

On a few occasions during the study period, rainfall tended to be concentrated into short periods of heavy down pour occurring in the afternoon or at night. Large drop sizes resulted in visible surface runoff. More common, however, were light late afternoon showers. Most of this rainfall was lost through evaporation especially if there was an interval of dry hot days between the shower events. Records from the Meteorology Department, showed that the probability of receiving a mean annual rainfall of 750-1000 mm is 10%. It is evident that evapo-transpiration in the study area, exceed the amounts of rainfall received (see Table 1 below). Relative humidity is an important index of the amount of moisture in the air, which also indicates the ability of given air conditions to result in precipitation. The average relative humidity for the study area is 89% at 0600 GMT and 70% at 1200 GMT.

The main source of water for both the people and livestock are dams. During long dry periods, these dams dry up and water becomes a scarce commodity in this area. The government has tried to alleviate this problem by sinking boreholes but the numbers are too few for the needs of the current human and livestock populations. The main land use activity within the study area is livestock production. Limited cultivation of annual crops like millet, sorghum and maize is done during the wet season.

Table 1. Mean Monthly and Annual Rainfall (mm) and Evapo-transpiration (mm) in the study area 1998-2002.

Month	Rainfall (mm)	Evapo-transpiration (mm)
January	34	152
February	54	144
March	102	152
April	182	124
May	146	118
June	78	108
July	82	110
August	122	116
September	120	124
October	132	132
November	114	134
December	64	142
Annual Average	1230	1556

Source: Meteorology Department, Kampala.

Experimental animals

Sixteen four-month old local male sheep of approximately 16 ± 0.1kg each were purchased from the study area and routinely treated against internal and external parasites. They were all housed in individual pens in the same barn and fed the same diet comprising low quality hay. The animals were randomly assigned to four watering regimes in a completely randomised design (CRD). At the end of a preliminary period of one month, data collection commenced and continued for the next nine weeks.

Experimental treatments and procedures

The watering treatments consisted of *ad-libitum* watering (T_1), watering once daily (T_2), once every two days (T_3), and watering once every three days (T_4). Ten litres of water were offered in individual plastic buckets placed securely within each pen according to the treatment. T_1 had access to water at all times of the day. Animals in other treatments had access to water for 30 minutes in the afternoon (3.00 - 3.30 p.m.) according to their respective watering regimes. This duration was determined after a thorough observation of the drinking habits of the animals during the preliminary period. The amount of water consumed was calculated as the difference between the amount offered and amounts refused.

The mean water intake per animal was computed by dividing the total water intake of all the animals by the number of animals. The experimental feed comprised 50% legume/grass hay mixture, 49% maize bran constituted and 1% mineral premix. Feed was offered *ad-libitum* with each day's offer being adjusted on the basis of the previous day's intake. The high ash (calcium and phosphorus) content of the experimental diet was mainly attributed to the high proportion of fodder legumes.

Data collection and statistical analysis

Feed remaining in the troughs at the end of 24 hours was weighed and recorded daily on individual animal basis using a sensitive weighing scale. The feacal material from each animal was also weighed and recorded daily on individual basis using a different weighing scale. Faecal collection started 24 hours after the initiation of the experiment. The DM content of the feed and faeces was obtained after oven drying the samples and then analysing them in the laboratory. The chemical composition of the feed is shown in table 2.

Table 2. Chemical composition (%) of the feed

DM	Ca	P	EE	CP	ADF	NDF	Ash
98	0.11	0.88	3.8	9.56	60	44.66	5.05

The experimental animals were weighed individually at the start of the trial and, thereafter, weekly, until the end of the trial. Weighing was carried out prior to feeding and watering. Data were subjected to Fisher's one-way analysis of variance (ANOVA) Where treatment effects were significant, mean separation tests using Duncan's New Multiple Range Tests were conducted (Steel and Torrie, 1980).

The following model was used:

$Yij = \mu + Ti + Eij$

Where Y = observation

μ = Overall mean

Ti = treatment effect

Eij = residual effect

i = treatment

j = replication

Regression analysis was used to determine whether there was a significant relationship between watering frequency and water consumption, feed intake, feed digestibility and body weight changes.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

Effects of watering frequency on daily water intake, feed intake and digestibility

The mean daily water intake, dry matter intake and dry matter digestibility are presented in Table 3.

Table 3. Mean (± SE) daily water intake (l^{-1}), dry matter intake (gd^{-1}) and dry matter digestibility (%)

Treatments	Water intake	DMI	DMD
T1	2.17 ± 0.05^{a}	19.13 ± 8.19^{a}	73.63 ± 0.51^{a}
T2	$.67 \pm 0.04^{b}$	514.0 ± 7.53^{b}	72.63 ± 0.57^{a}
T3	0.98 ± 0.03^{c}	442.75 ± 7.63^{c}	66.13 ± 0.51^{b}
T4	0.66 ± 0.01^{d}	407.50 ± 2.79^{d}	63.75 ± 0.92^{c}

Means in the same column with different letter superscripts are significantly ($P<0.05$) different.

There was a significant ($P<0.05$) difference in water consumption among the treatments. Average daily water consumption was highest among sheep under T_1, followed by the sheep under T_2, T_3 and T_4, respectively. Sheep under T_1 consumed water at a rate of 10% of their body weights, while those under T_2, T_3 and T_4, consumed 8%, 5.2% and 3.7% of their body weights respectively. Overall, water intake decreased with increase in the duration of water deprivation. Animals under T_4 consumed about 3 times less water than the T_1 animals while T_3 and T_2 animals consumed 2 and 1.3 times less water than T_1 animals, respectively. Therefore, the percentage of water consumed by animals in each treatment in comparison to the water consumed by T_1 animals was 30%, 45% and 77% for T_4, T_3 and T_2, respectively. This indicates that when animals are watered *ad-libitum*, they drink more water than when they are given water intermittently. Little *et al.* (1978) suggested that sheep under *ad-libitum* watering may be assumed to be in water balance, and a large proportion of the difference between their water intake and losses can be accounted for by losses through feaces, urine, sweat and breath. This difference between water intake and losses was much smaller in the deprived sheep, suggesting that either their respiratory losses were smaller or that they were in negative water balance as indicated by the dry nature of the feaces and less urine output. Both these factors probably contributed to the difference.

In line with the results of our trial, Thickett *et al.* (1981) had also noted that when sheep are provided with unlimited amount of water, they drink more than when it is restricted. Likewise, a significant increase in water consumption by the sheep under *ad-libitum* watering regime was observed by More and Sahni (1978). This is in agreement with Clark and Quin (1949a) who noted that in sheep when the intervals between watering sessions were extended to 3 or 4 days, consumption fell to 63 and 54%, respectively, of that of the sheep on *ad-libitum* watering. Similarly, Chesworth (1992) reported that animals would drink more water when they can get it. So, cattle which have water available only every few days may actually drink 25 to 30% less water than those which have continous access. Payne (1966) also reported that water deprivation appears to reduce the total water intake of cattle. French (1956) showed that deprivation of water for 48 and 72 hours at a time reduced the water intake of stall-fed *Bos indicus* cattle by 12 and 30.7%, respectively.

From the above results, it is clear that water consumption varies appreciably with frequency of drinking. This is in full agreement with the results of our study, which clearly showed that water consumption declined according to the duration of water deprivation. Under the conditions of our study, it was observed that deprived sheep produced less urine and feacal output, which became severe as the deprivation period increased.

The results showed that watering regimes had a significant ($P<0.05$) effect on the amount of dry matter consumed. Animals under T_1consumed DM at 3% of their body weights while those in T_2, T_3 and T_4 consumed 2.5, 2.4 and 2.3% of their body weights, respectively. DMI by the sheep in T_2, T_3 and T_4 were lower than those of T_1 animals in which the sheep had *ad-libitum* watering. Our results agree with those of Preston and Nuwanyakpa (1986) which also reported that sheep on *ad-libitum* watering frequency consumed more feed, drank more water and gained weight faster than those on intermittent watering.

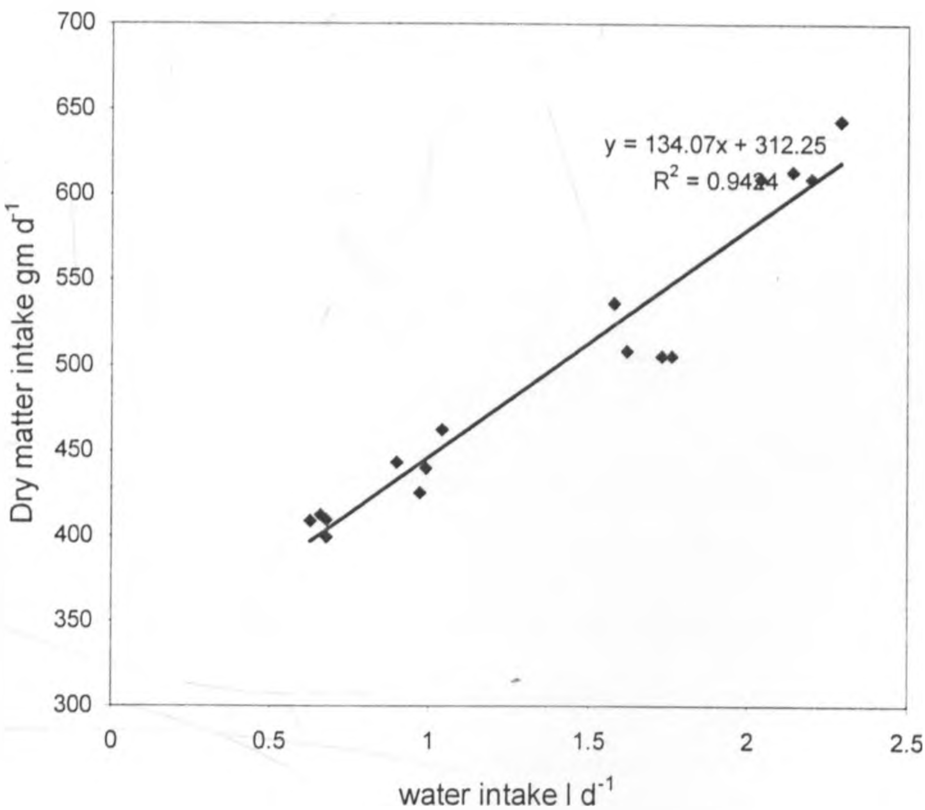
Our results are also in agreement with those of Gordon (1965), Macfarlane *et al.* (1961) and More and Sahni (1978 and 1981), that in general indicated that feed intake decreases progressively with increase in the period of water deprivation, with concomitant reduction in the mean DMI. Similar results were reported in buffaloes (Mehta and Ludri, 1976), steers (Utley *et al.* 1970), lactating dairy cows (Little *et al.* 1975) and on cattle (Thornton and Yates, 1968 and Little *et al.* 1978) where a significant reduction in DMI with increase in water deprivation was observed.

A certain amount of water is necessary for normal passage of feed through the digestive tract and in the absence of adequate water, DM will be accumulated in the digestive tract, probably in the rumen (Hailay, 1998). This is in line with the observation of Balch *et al.* (1953) where water restriction tended to reduce the rate of passage of feed residue. Similarly, Gordon (1965) indicated that for rumination to proceed normally, there must be sufficient fluid in the reticulo-rumen, and that transport of ingesta from the reticulo-rumen through the omasum to the lower tract requires an adequate supply of water, which is provided mainly by drinking. Therefore, during water deprivation, the amount of water consumed is reduced, and thus the reticulo-rumen receives insufficient supply of water to allow normal feed intake as well as rumination. Musimba (1986) reported that water restriction in domestic ruminants leads to a decline in feed intake by cattle, sheep and goats. Similarly, Singh et al. (1976) observed loss of appetite and decline in feed intake of East African cattle and sheep watered after 72 or longer hours.

In line with the above findings, our study also showed that water-deprived sheep had depressed appetite and consumed less water, which increased as the period of water deprivation increased which, in turn, depressed the DMI. French (1956) recorded similar observations in Zebu steers where he reported that with restriction of water intake, there was a significant decrease in the average daily DMI. He also noted that the quantity of digestible crude protein available to the animal decreased significantly with less frequent water intake, and that feed intake dropped by 6 and 8% when steers were drinking once within 48 and 72 hours, respectively. Clark and Quin (1949b) also noted a significant drop in consumption of hay by sheep watered twice weekly. The appetite decreased progressively until the animals were watered again. The average daily hay consumption per sheep in a two-year experiment was 1.21 kg in sheep watered *ad-libitum* and 0.8 kg in the water-restricted sheep.

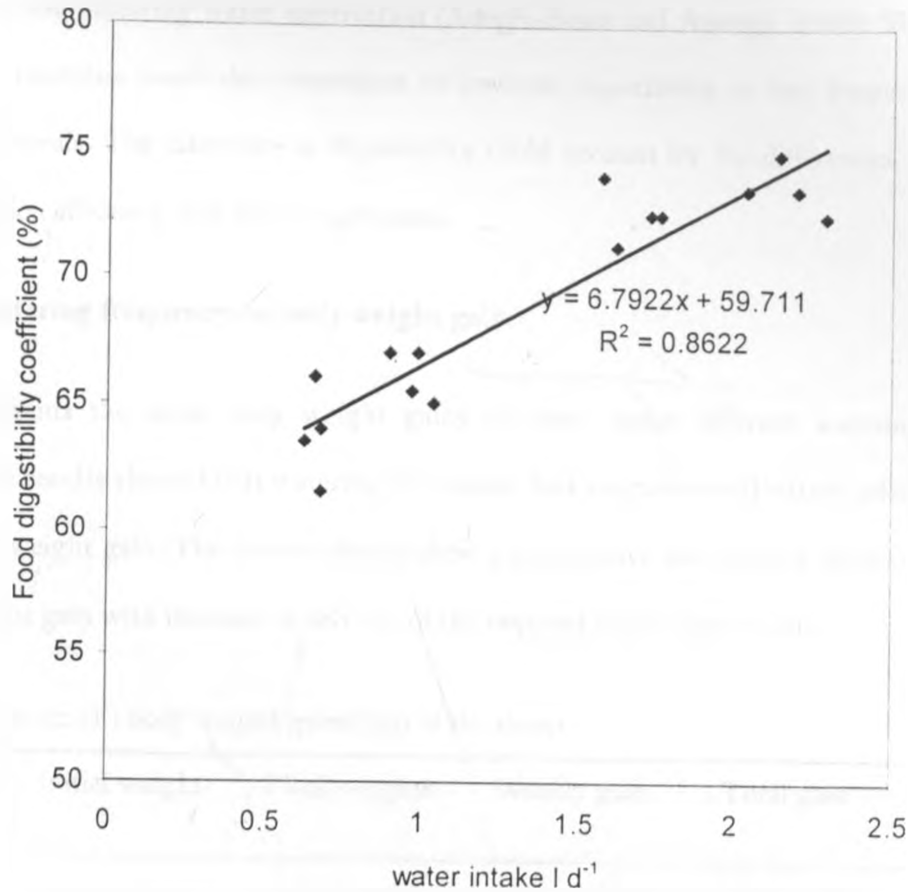
Maloiy (1973) in another study noted that watering Zebu cattle once every 48 or 72 hours, as practised by pastoral nomads in East Africa result in substantial decrease in DMI. Payne (1966) also reported that inadequate supply of drinking water depressed DMI and the higher the ambient temperature, the more severe the restriction was. Bohra and Ghosh (1977) reported proportional reductions in DM and digestible energy intake in water restricted sheep. Castle and Thomas (1975) also observed a significant positive relationship between water intake and DMI. In our study, about 94% of the variation in DMI was correlated to water consumption. Winchester and Morris (1956) and Castle (1972) also reported that water intake in ruminants is a function of DM consumption and ambient temperature. These reports are consistent with those of Owen (1976) which indicated that wethers consume about 2kg of water for each kilogram of dry feed, in addition to a predicted requirement of almost 2kg of water when no feed is eaten.

Figure 1 The relationship between water intake and dry matter intake



The results showed that watering regime had a significant ($P<0.05$) effect on the average DM digestibility. Overall, there was a positive correlation between DM digestibility and water intake ($R^2=0.86$) implying that about 86% of the variability in digestibility could be correlated to variability in water intake. Dry matter digestibility in T_1 was not significantly ($P>0.05$) different from that in T_2 indicating that the dry matter digestibility of feed consumed by animals watered *ad-libitum* was not significantly different from that of the animals watered once daily. However the feed digestibility was significantly higher ($P<0.05$) in T_3 than in T_4, suggesting that animals watered once every two days have significantly higher digestibility than those watered once in three days.

Figure 2 The relationship between water intake and food digestibility



Our results agree with those of Adogla-Bessa and Aganga (2000) which also showed high feed digestibility with more frequent watering in *Tswana* goats. Similarly, our results also agreed with those of French (1956) which showed a general decrease in the digestibility of crude protein when water intake by zebu oxen was restricted to once every 72 hours. A water medium is necessary for both the physical softening of feed and the biochemical activity of the rumen microbes. An adequate supply of water could, therefore, aid the breakdown of feed, and hence facilitate the fermentation and digestion process. Rapid fermentation accounted for the higher digestibility observed when watering was more frequent. Furthermore, the number of rumen bacteria and protozoa tend to decrease following water deprivation (Adogla-Bessa and Aganga, 2000). The decrease in microbes could also contribute to lowered digestibility at less frequent watering intervals. The difference in digestibility could account for the differences in feed conversion efficiency and daily weight gain.

Effect of watering frequency on body weight gain

Table 4 presents the mean body weight gains of sheep under different watering regimes. The results showed that watering treatments had a significant ($P<0.05$) effect on the body weight gain. The results clearly show a progressive and marked decrease in body weight gain with increase in severity of the imposed water deprivation.

Table 4. Mean (± SE) body weight gains (kg) of the sheep

Treatments	Initial weight	Final weights	Weekly gain	Total gain
T1	16.13 ± 0.12^{a}	21.63 ± 0.24^{a}	0.61 ± 0.20^{a}	5.50 ± 0.20^{a}
T2	16.25 ± 0.14^{a}	20.25 ± 0.20^{b}	0.44 ± 0.22^{b}	4.00 ± 0.22^{b}
T3	16.25 ± 0.14^{a}	18.83 ± 0.12^{c}	0.29 ± 0.22^{c}	2.58 ± 0.22^{c}
T4	16.13 ± 0.12^{a}	17.50 ± 0.08^{d}	0.15 ± 0.07^{d}	1.37 ± 0.07^{d}

Treatment means in the same column with different letter superscript are significantly different ($p<0.05$).

The initial body weight of all the experimental animals was approximately similar (16.0 ± 0.1kg). By the end of the experimental period, sheep in T_1 gained about 34% of their initial body weight, while those in T_2, T_3 and T_4 gained 25, 16 and 8.5% of their body weight, respectively. These results are in agreement with those of Clark and Quin (1949b) who reported that sheep maintained their body weights during periods that they received water every second and third day. Maloiy (1973), reported that camels and Somali donkey continued eating normally following water restriction.

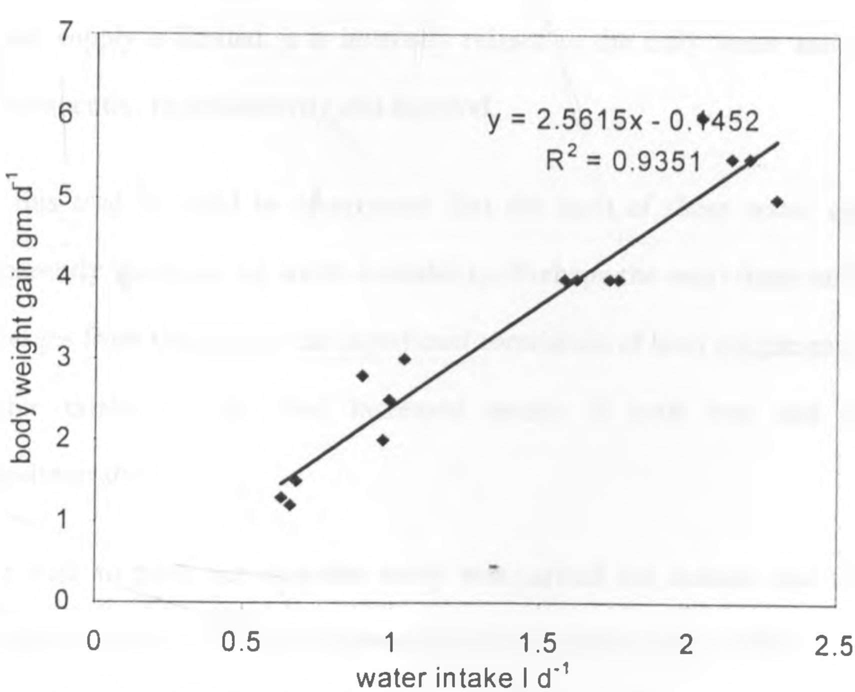
Feed intake only declined when the camel had no access to water for 30-40 days. Generally, ruminants adapted to the arid and semi arid lands have the ability to maintain feed intake under heat stress and dehydration. They also regulate their body temperature by utilizing water when environmental temperature is high and water is scarce (Maloiy 1973). This could partly explain why in our study, no loss in body weight was reported. Since all the experimental animals were under the same management practices except, watering, the observed differences in body weight could only be attributed to water restriction. This indicated that water restriction had a negative impact on feed intake. These results agree with those of French (1956) and Payne (1966) which indicated reduced feed intake which, in turn, led to decreased body weight gain as a result of deprivation of water in cattle. Church and Pond (1978) and Little *et al.* (1975) reported that deprivation of water, even to a moderate extent, results in decrease in intake and low body weight gain. The reduction in body weight during water restriction may be due to lesser body water (Payne, 1966) but in the present study it may also be due to the reduction in DMI which might have indirectly affected the body weight by reducing the bulk of feed in the reticulo-rumen.

Apart from reduced water and dry matter intake, it was noted in this study that the sheep that were on the 3-day watering regime were more listless than those drinking more frequently. Their skins were drier and old skin scars became more obvious. The animals produced much drier feaces, coated with mucus.

Most probably, more severe effects would have occurred if the animals were free ranging with animals under the highest water deprivation deteriorating more rapidly.

Comparison between the final body weights and the corresponding weekly weight gains revealed a significant ($P<0.05$) effect of watering treatments. The watering frequency significantly affected both the final and weekly weight gains. There was a positive linear relationship ($R^2 = 0.94$) between water intake and body weight gain. Hence about 94% of the variation in body weight gain was correlated to the variation in water intake, figure 3.

Figure 3 The relationship between water intake and body weight gain



CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

The results of this study indicated that in all parameters considered, watering frequency had a significant effect. Under the conditions of the study, watering at least once daily could achieve the best results of sheep production in the study area. Therefore improvement of drinking water for sheep in areas where the water resources are very scarce and environmental conditions very harsh by providing more watering points can greatly improve sheep productivity.

It can be concluded basing on the information obtained from this trial that although intermittent watering saves water which could assist survival of more animals where water supply is limited, it is inversely related to the daily water and feed intake and, consequently, to productivity and survival.

In this trial, it could be ascertained that the limit of sheep water consumption was apparently governed by water availability. Perhaps the most important feature, which emerges from this trial, is the significant correlation of both weight gain and DMI with water intake. In the trial increased intake of both feed and water occurred simultaneously.

We wish to point out that this study was carried out indoors and the experimental animals were handfed. The results of the study therefore may differ with a study carried out under grazing conditions where animals have a choice of selecting plants and plant parts of variable moisture content.

In the study we did not get any negative body weight change in any treatment. Even the treatment with the three days of water deprivation showed a slight gain in body weight. The economy of water use therefore is a desirable feature for livestock during hash weather conditions.

In conclusion, it was noted that free access to water is the ideal situation in which animals would perform best. Lack of adequate amount of water adversely affects feed intake and its digestibility and hence animal performance, ultimately. However since free access to water is not possible under arid and semi-arid conditions, our results suggest that animals should be watered at least once a day for reasonable performance.

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APPENDICES

APPENDIX 1.

ANALYSIS OF VARIANCE ON WATER INTAKE

Source of variation	d.f.	s.s	m.s	v.r	f pr.
Treatment	3	5.536	1.845	329.91	<0.05
Residual	12	0.067	0.005		
Total	15	5.603			

APPENDIX 2

ANALYSIS OF VARIANCE ON FEED INTAKE

Source of variation	d.f.	s.s	m.s	v.r	f pr.
Treatment	3	104605.9	34868.6	183.56	<0.05
Residual	12	2279.4	190.0		
Total	15	106885.4			

APPENDIX 3

ANALYSIS OF VARIANCE ON DRY MATTER DIGESTIBILITY

Source of variation	d.f.	s.s	m.s	v.r	f pr.
Treatment	3	279.283	93.094	54.35	<0.05
Residual	12	20.555	1.713		
Total	15	2999.8			