# THE EFFECT OF WATER DEPRIVATION AND ATROPINE ADMINISTRATION ON GASTRO-INTESTINAL FUNCTION IN GOATS

by

ABDULWAHID AJIBOLA

Supervisor : Dr E A Boomker

Co – supervisor : Prof J G van der Walt

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# DEDICATION

To

Almighty Allah

Who taught by the pen

He taught man what he knew not

and

Prophet Muhammad

who encouraged the search

for knowledge as distant as China

## GLORIFICATION

So high was the aspiration

Journey too long for decimation

On the road there was obstruction

Thorns alongside to cause vulneration

Fear and anxiety leading to sublimation

Alas ! Hurdles jumped with determination

Lofty heights subdued for prestigious elevation

That's enough a cause for jubilation

But there's need to exercise caution

Because this another form of examination

As tunnels still lie ahead for penetration

Also very high is folk's hope and expectation

With Allah all these will be easy manifestation

In His name oceans crossed without partition

By His might mountains climbed without frustration

To all one's puzzles He alone can profer solution

So I raise my palms up here goes the supplication

Make me a servant who will always show appreciation

After every relief and each one of Your proclamation

To Allah alone belongs appreciation and glorification

# ACKNOWLEDGEMENTS

"God Most Gracious !.....He has created man: He has taught him speech (and intelligence)..... Then which of the favours of your Lord will ye deny ?" (Holy Qur'an 55:1-13)

".....O my Lord ! Grant me that I may be grateful for Thy favours which Thou hast bestowed on me....." (Holy Qur'an 27:19)

Praise be to Allah by Whose grace another feather is added to my cap today. May His choicest blessings be upon the seal of messengers, Prophet Muhammad, his family, his associates and all those who follow their path from the beginning till the end of time.

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"...This is by the grace of my Lord! To test me whether I am grateful or ungrateful! And if any is grateful, truly his gratitude is (a gain) for his own soul; but if any is ungrateful, truly my Lord is free of all needs, Supreme in Honour." (Holy Quran 27:40)

# QUOTATIONS

"There is no moving creature on earth but its sustenance dependeth on God....." (Holy Qur'an 11: 6)

".....And produced therein all kind of things in due balance. And We have provided therein means of subsistence, for you and for those ye are not responsible. And there is not a thing but its (sources and) treasures (inexhaustible) are with Us....." (Holy Qur'an 15:19-21)

".....As the rain which We send down from the skies: by its mingling arises the produce (plants) of the earth – which provided food for men and animals....." (Holy Qur'an 10:25)

"Prudency is not only the ability to use things very well when plenty but also the display of strategic management amidst gross scarcity." – Abdulwahid

"Efficiency is not only the use of abundant resources for optimum production but the ingenuity to utilize even limited and deteriorating materials for best results." - Abdulwahid

# ABBREVIATIONS

| | |
|---|---|
| ADF | Acid detergent fibre |
| conc | concentration |
| CP | Crude protein |
| Dig | Digestibility |
| DM | Dry matter |
| g/d | grams per day |
| g/dL | grams per decilitre |
| GIT | Gastro – intestinal tract |
| G No | Goat number |
| Ht | Haematocrit |
| Kg/d | Kilograms per day |
| L | Litres |
| L/d | litres per day |

| | |
|---|---|
| mg/kg | milligrams per kilogram |
| mg/kg BW | milligrams per kilogram Body weight |
| mmol/d | millimoles per day |
| mmol/L | millimoles per litre |
| mOsm/kg | milliosmoles per kilogram |
| N | Nitrogen |
| PCV | Packed cell volume |
| pers obs | Personal observation |
| SD | Standard deviation |
| TPP | Total plasma protein |
| Vol | Volume |

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# ABSTRACT

The effects of limited and infrequent drinking, and atropine administration on feed intake and utilization was investigated in South African indigenous goats. Sixteen goats with an average body weight of 29.1 kg were subjected to water restriction and deprivation with concurrent atropine administration. They were fed *ad libitum* with a mixture of lucerne (*Medicago sativa*) and eragrostis hay (*Eragrostis curvula*), blended with molasses. The diet contained 10.47% crude protein, 38% crude fibre and 17.5 MJ/kg gross energy.

Fifteen goats were randomly divided into 3 groups and were watered *ad Libitum,* 50% of *ad libitum* and 30% of *ad libitum* water intake respectively (Trial 1). In trial 2, a group of 8 animals were deprived of water for 3 days while the other group had free access to water daily (phase1). During phase 2, another group of 8 were watered on the 5$^{th}$ day while others had water *ad libitum.* A subgroup of 4 goats each were injected with atropine in both phases.

The results showed that these goats have high water efficiency. The limited and infrequent supply of water decreased feed intake but enhanced nutrient utilisation. The provision of water at the 50% *ad libitum* level or once in 3 days is economical and beneficial to goat production in water-scarce areas. There is a need for complimentary investigations using atropine at high doses to further elucidate the effects of this drug on the gastro-intestinal functions of ruminants.

# CHAPTER ONE

# INTRODUCTION

## 1.1 GENERAL INTRODUCTION

The goat belongs to the polygastric group of domestic animals due to the presence of a compound stomach made up of a rumen, reticulum, omasum and abomasum. They are generally referred to as ruminants because of their ability to regurgitate food from the rumen for more thorough chewing and reswallowing, a process known as rumination. Goats can feed on short grasses of low quality not normally eaten by other domestic animals thus converting poor roughages to edible meat and milk, thereby serving as a cheap source of animal protein.

Many grasslands in Southern Africa are used for animal husbandry/ production. Therefore, extensive animal production is of tremendous importance, both for potential export and also to meet the rising local demand for animal protein in the subregion [Serfontein (1989); Ajibola (1995)]. The prevailing conditions in these grazing zones often leads to a scarcity of feed and water with adverse consequence on production. However, goats are well adapted to arid climates and have low water requirements [Gihad (1976); Devendra (1980); More and Sahni (1981); Silanikove (1992)].

They can travel long distances in search of food and water. Despite these harsh conditions, there may be a need to administer drugs either for prophylaxis or treatment. Such drugs may have some side effects in addition to their therapeutic values. An example is atropine, which is used in some anthelminthic preparations, but also has some inhibitory effects on digestive functions. Hence there is need to investigate the performance and production of this animal species under stressful condition similar to natural circumstances and also to

include the administration of atropine. This is with a view to establish the level of stress the animal can tolerate with minimal or no loss of production (body weight).

## 1.2 DIGESTION IN GOATS

Goats can utilise many hard, dry and high-fibre food materials, which are often rejected by other grazing stocks. This includes spines, thorns, bristle, shrubs, weeds and trees [Mackenzie (1970)]. It has been observed by Chanda et al (1951) that the goats' diet includes 15 per cent more species of plants than that of other domestic ruminants (cattle and sheep). This might be due to its relative larger rumen capacity than sheep in addition to its higher digestibility efficiency of poor roughage compared with cattle and sheep, as noted by Devendra and Burns (1970). This food is diluted with large volumes of saliva normally secreted by this animal species during feeding and rumination.

The saliva secretion, coupled with the large rumen that acts as a water store especially during unfavourable climatic condition, contributes to the survival of Bedouin goats and other desert inhabiting livestock. In one study, Shkolnik and Choshniak (1984) noted that Bedouin goats in the extreme deserts of the Middle East, given water only once every 2-4 days thrived on low quality pasture. It was suggested that infrequent feeding might help these desert ruminants to balance their energy metabolism during the dry summer.

Blaxter et al (1950) noted that a dry diet with restricted water supply would tend to fatten a goat. This is of importance in animals bred for meat production. It has been observed over the years by Mackenzie (1970) that goats utilise this type of diet prior to the breeding season with the effect of reducing their milk yield and increasing their body reserves (of flesh and fat). This was supported by Balch et al (1953) that water deprivation might lead to an increased compensatory saliva

production, a condition that facilitates an increased rumen fermentation rate. It has also been observed that ruminants exposed to dehydration conserve water excretion by hormonal control [English (1966); More and Sahni (1981)].

## 1.3 ATROPINE; USES AND EFFECTS

Atropine is a parasympatholytic drug that reduces the amount of acetylcholine released to the muscarinic receptors by parasympathetic postganglionic nerve fibres, thus inhibiting the parasympathetic division of the Central Nervous System (CNS). It is often prepared as atropine sulphate for administration by parenteral routes.

It is used in surgery for premeditation, especially in those cases involving the use of volatile, irritant anaesthetic agents and for the treatment of reflex-mediated bradycardia, by blocking the effects of impulses in the vagus nerve. In addition to surgical application, it is used as an antidote to organophosphate poisoning and as an adjunct to some anthelminthic, ectoparasitic and other medicinal preparations of therapeutic importance. Other uses include antiperistalsis in embryo transfer, treatment of peptic ulcers and certain cases of glaucoma in ophthalmology [Eger (1962); Meyers and Tomeldan (1979); Murad et al (1981)].

Atropine causes inhibition of saliva and other exocrine secretions. It affects gastro-intestinal motility by reducing propulsive activity and certain forms of strong contractions. In one study by Ruckebusch (1987), it was observed that atropine depressed the intrinsic motor activity of the rumen. Other effects of atropine are broncho-dilation, relaxation of smooth muscle of the ureters and urinary bladder, the latter leading to the inhibition of urination. It may increase heart rate, hence its use in the treatment of vagal-stimulated bradycardia, cycloplegia and mydriasis (assisting in certain cases of glaucoma).

## 1.4 STUDY OBJECTIVES

The purpose of these studies is to provide an integrated examination of the effects of infrequent drinking and water restriction vis-à-vis inhibited saliva secretion (via atropine administration) on feed intake and utilization in South African indigenous goats. These effects would be assessed by examining the total energy intake, digestible energy intake, organic matter intake and feed digestibility by the animals. Other parameters to be measured are water intake and loss as well as urinary and faecal output.

Previous experiments have studied the effects of water restriction on digestive functions in ruminant animals while some focused attention on the effects of atropine on the digestive processes of these animals in the hydrated status [Duncan (1954); French (1956); Cottrell and Iggo (1984); Gregory (1984); Silanikove (1985); Utley et al (1970); Qinisa and Boomker (1998)]. Hence there is a need to investigate the effects of this drug on the digestive function in ruminants under controlled conditions of water deprivation which simulate natural conditions. The information received from this study may assist in reducing the number of animals dying in remote areas due to water deprivation and absence of quality feed. It will also improve the knowledge of clinicians who are involved in the day-to-day use of atropine in ruminants. The study may also stimulate further research on the use of atropine vis-à-vis animal digestion.

# CHAPTER TWO
# LITERATURE REVIEW

## 2.1 FEEDING BEHAVIOUR

The goat has a mobile upper lip which, in conjunction with the lower mandible (lip), it uses to actively pull the food material into the mouth. This attribute can increase its efficiency as a browser rather than a grazer, as it prefers the leaves of bushes and trees to grass. Unlike other domestic ruminants, it has often been seen standing on its hind legs (bipedal stance) against tree trunks and branches to strip the young green material from the shoots [pers. obs]. The goats select and browse on various feed materials, mostly fibrous, low quality diets, including trees such as elm, ash, hazel, willow weed and *Quercus* species (oak weed); shrubs such as brambles, briars, ivy gorse and ling heather and roots which include potato, mangolds, sugar beet, swedes and turnips [Wilson (1977); Nastis and Malechek (1981); Kingsbury (1983); McCabe and Barry (1988);]. Asdell (1950) noted their relish for forage crops like maize, mashlum, artichokes, chicory, comfrey and sweet blue lupin.

Some meat-producing (Spanish) and Angora goats were used in brush weed control programmes in California to control chaparral. The importance of goats in a weed control system was documented by Sidahmed et al (1981, 1983), who found that shrubby chaparral species (chamise, scrub oak and manzanita) were well utilised by this species. In New Zealand, Howe et al (1988) made similar observation in goats fed *Ulex europaeus* (gorse) – a leguminous shrub that was digested more efficiently by goats than by sheep. Both small ruminants are, however, efficient in the biological control of numerous poisonous plants that include *Senecio* species, leafy spurge, larkspur, *Brassica* species [Goeger et al (1982)]. Kale and rape are also well utilised by goats without causing any toxicity problems. Cull onions containing haemolytic factors similar to the anaemia factor in *Brassica*

are much less toxic to the small ruminant than to cattle. The supremacy of these small ruminants especially goats, in weed control can be best summarised in the words of Kingsbury (1983) who commented on the ability of these species to surmount physical barriers preventing their access to plants. He aptly states: "Thorns are not always an effective defence. Anyone who has watched a goat consume black locust (*Robinia pseudoacacia)* branches, thorns and all, will be forced to that conclusion". There is even no age limit to this ability. Asdell (1950) documented: "The most tender-mouthed kid will engulf the fully armoured head of a spear thistle with pleasure." Goeger et al (1982) have also observed the tolerance of goats to natural toxicants such as pyrrolizidine alkaloids. Nastis and Malechek (1981) made a similar observation in a study involving goats fed diets containing up to 80% immature oak (*Quercus* species) and 9% tannin.

The potential of goats seems to be under-utilised or unappreciated in waste management. It has been noted, quoting NRC (1981), "The goat offers an opportunity, sometimes the only alternative, for deriving value from a vast reservoir of natural resources and unwanted assortments of herbage, shrubs, tree leaves, and plant refuse and by-products." Several refuse and by-products such as poultry feed waste, urea, bran, oats, sugar beet pulp, maize germ meal and maize residues from flourmills can be used in the diets of meat-producing and dairy goats alike. Reed and Brown (1988) observed in a Californian study that there was no change in milk production of dairy goats when a mixture of almond hulls and urea was used to replace lucerne meal in their diets. Leaves of tree legumes such as leucaena, gliricidia and sesbania are useful feed supplements [Van Eys et al (1986)]. In the tropics, agro-industrial by-products such as banana and plantain wastes (stalk, leaf, pseudostem and peels) can be used as foodstuff for goats [Poyyamozhi and Kadirvel (1986)]. The author has also observed over the years in tropical West Africa that these small ruminants eat waste such as yam and cassava peelings with relish [pers. obs]. In the rural communities of this sub continent (West

Africa), even the tubers of plants which are processed for human consumption (yam and cassava) and domestic use (starch), are not spared from these goats, that are often seen consuming these processed plant materials when these are spread on the field for sun-drying or compressed for reduction of toxic metabolites. One can therefore conclude that goats can serve as natural utilisers since they convert waste and refuse to edible meat and milk. It appears that this capacity for waste recycling by goats is not yet fully exploited in goat husbandry.

Some variations have also been observed in the feeding patterns of small ruminants, especially goats. These are seasonal changes in foraging habits and diurnal variations of grazing locations. During a study by McCamman-Feldman (1980) reported by Kronberg and Malechek (1997) on goats in Nicaragua's tropical savannah, there was a distinct seasonal change in the foraging habits of goats as they ate more leguminous browse or forbes during the dry season than in the wet season (when they prefer grazing). It might be of interest to goat meat producers that the dry season is an ideal period for fattening their animals, as there is an ample supply of browse materials available. Van Dyne et al (1980) pointed out the flexibility in the diet of the goat when they catalogued the wide selection range of vegetation classes consumed.

Similar observations were made in sheep, especially during the dry season. This led Pfister and Malechek (1986) to the conclusion that neither goats nor sheep can be rigidly characterised as grazers or browsers. However as pointed out earlier several other authors [Maher (1945); Schneider (1947); Bell and Lawn (1957); Wilson (1957); Harvey and Rigg (1964); McMahan (1964); Knight (1965); Butterworth (1967); Devendra (1967); Gihad (1976); Bell (1978)] concluded that goats do tend to be more browser than grazer.

Another variable in the feeding pattern of small ruminants is the diurnal variation that is found in the location of their grazing zones. Arnold and Dudzinski (1978) observed frequent changes in the location where grazing takes place during the day. It is uncertain as to whether this is due to the selection of feed by the animals or merely a reflection of changes in the degree of satiation. A possible explanation put forward by Jones and Mangan (1977) is that leaf cells and chloroplasts are ruptured as ruminants masticate the vegetation leading to the subsequent release of nutrients that prompt degradation by rumenal microbes. Thus it is not surprising that levels of rumen metabolites and nutritionally related hormones change within minutes after feeding commences [Chase et al (1976); de Jong (1985)]. Environmental factors such as the degree of soil and the moisture content of vegetation during the rainy season might also influence the various responses observed in these animals. Goats being a very (sensitive and) selective breed may be less willing to forage in a wet environment than sheep [Kronberg and Malechek (1997)].

Another topic of interest in the feeding behaviour of ruminants is rumination. This is a characteristic of all ruminants involving the passage of a bolus of rumen ingesta into the mouth via the oesophagus for re-chewing. The time spent ruminating the ingested feed material is as important as that spent foraging. Kronberg and Malechek (1997) in their studies of free-ranging small ruminants estimated that the longest period of rumination by sheep and goats was approximately 9 and 10 hours per day, respectively. Other findings show that domestic animals hardly/seldom ruminate more than 10 hours a day [Welch and Smith (1969); Cammell and Osbourne (1972)]. However, one cannot categorically state that one species ruminates faster than the other because rumination is a function of several factors - the fibre content of the feed being one of the most important. Some investigators have found that metabolic factors such as pH, osmotic pressure, the concentrations of rumen volatile fatty acids (VFA) and blood acetate influence the rumination time [Focant et al (1979); Welch

(1982)]. In one study by Silanikove (1992), it was discovered that, for identical feed intake, sheep ruminated longer than did goats. Some possible reasons for this variation in rumination time are the salivary secretion, rumen motility and the smaller particle size which facilitates passage through the reticulo-omasal orifice into the omasum and subsequently into the abomasum after rumination [Bell (1984)].

## 2.2 NUTRIENT REQUIREMENT

Small ruminants, especially goats, are intermediate feeders with selective feeding habits and have a greater propensity for browsing than grazing. This is an adaptation to meet their high nutrient requirement. Goats have higher metabolizable energy (ME) requirements for maintenance than other ruminants and thus consume larger quantities of browse than sheep [Mohamed and Owen (1981)]. MCabe and Barry (1988) made similar observations in goats and sheep fed willow (which is high in tannin and lignin). The voluntary ME intake of goats was higher than that of sheep in this study. Earlier reports by Wilson (1977) also corroborated this finding.

Some researchers [Pfister and Malechek (1986); Van Eys et al (1987)] recommend the use of foodstuffs like cassava, sugar cane residues, molasses and soghurm as energy supplements in the developing countries. Goats are known to be better utilisers of fibrous, low-quality diets than other ruminants in the tropics [Devendra and Burns (1970); El-Hag (1976); Gihad (1976); Devendra (1978); Gihad et al (1980); Devendra (1981); Howe et al (1988)]. This difference was attributed to the nature of tropical forages that are composed of plants having widely different nutritive values [Van Soest (1982)]. Goats are known to be selective browsers unlike sheep and as such can select the most digestible parts of the food to meet their nutrient requirements. However the digestion of forages grown in the temperate countries has proved to be identical in both sheep and goats [Schneider (1957); Baumgardt el al (1964); Jones et al (1972); Mohamed and Owen

(1981); NRC (1981); Pfister and Malechek (1986); Quick and Dehority (1986)].

Another major nutrient required by animals for maintenance of body weight is protein. Owen-Smith observed that protein may be the limiting nutrient in many forages, especially in the tropical countries [Owen-Smith (1982)]. This may be the factor leading to longer foraging time by small ruminants during the dry periods, as they spend more time searching through a large quantity of low-quality vegetation for dietary items with relatively higher levels of crude protein [Kronberg and Malechek (1997)]. Previous studies suggest that crude protein (CP) intake was less critical to goats when compared with other ruminants, as they are more efficient in utilising and recycling nitrogenous compounds [Watson and Norton (1982); Doyle et al (1984); Schacht et al (1992); Kronberg and Malechek (1997)].

However, a minimum of 5-6 % CP appears to be required, as there is a tendency for goats to make special efforts to obtain extra CP if supplied below this minimum [Gihad (1976); Antoniou and Hadjipanayiotou (1985)]. This propensity for increasing protein intake has been observed in goats and other ruminants alike by other investigators [Provenza et al (1983); Seagle and McNaughton (1992)]. Goats foraging on a shrub with 4.2% CP ate woodrat (*Neotoma lepida*) dwellings consisting of juniper (*Juniperus osteosperma*) bark and twigs soaked with urine [Provenza (1977) cited by Kronberg and Malechek (1997)]. Cattle grazing on shrub – dominated arid rangeland spent more time eating supplemental protein blocks when they ingested forage with low protein content [Provenza et al (1983)]. Moreover, wild grazing ungulates abound in greater density in regions of the Serengeti where greater nitrogen ingestion is possible [Seagle and McNaughton (1992)].

There are diurnal variations in the nutrient requirement of animals and human beings, which may be due to hormonal interplay or a reflection of changes in the satiety centre. Kothmann (1966) and Langlands (1965, 1967) reported that grazing ruminants increased dietary nitrogen content as the day progressed. Arnold and Dudzinski (1978) suggested that this was partly due to changes in the location of grazing during the day, perhaps because the animals became more selective. It has been observed in rats and humans (and presumably other mammals) that carbohydrates are most strongly preferred in the early hours of the feeding cycle, whereas desire for protein increases gradually over the course of the active cycle [Leibowitz (1992)].

There are some minor nutrients necessary for the normal physiological processes and productivity in animals. Most of these are obtained via endogenous routes in ruminants, but to enhance these syntheses, some important constituents must be present in the animals' feed. A diet lacking in fibre may lead to a deficiency of vitamins and other nutrients [NRC (1975, 1981)]. Asdell (1950) stated that fibre in the goat's diet is of great economic importance and that this should be fully exploited. He suggested that a high-yielding goat could obtain almost all its nutrient requirements from natural herbage during the greater part of the year. Other study revealed that the foraging times of small ruminants increase during the dry season, perhaps due to the increased nutrient demands from lactation [Kronberg and Malechek (1997)].

## 2.3 IMPORTANCE OF WATER

While water is not normally considered one of the nutrients required to meet the basic metabolic needs of an animal, its importance outweighs that of all these nutrients. In fact, it might even be classified as an essential nutrient. In the words of French (1956), starving animals may lose nearly all their glycogen and fatty reserves, half their body

protein and about 40 per cent of their body weight and still live, whereas the loss of only 10 percent of body water causes serious disorders while further losses may quickly lead to death. Stressing the importance of water further, French (1956) pointed out that temporary water shortages are consequently of greater immediate significance than corresponding deficiencies of solid foods.

The fundamental importance of water in animal nutrition includes its role in nutrient solution and absorption. Other uses of water include removal of noxious metabolic products from the urinary and alimentary tracts and the maintenance of body temperature. Water is a basic constituent of all living cells, and hence it is concerned with the maintenance of normal osmotic pressures and turgidity of the cells in the various organs of the body [French (1956); Choshniak and Shkolnik (1978); Brosh et al (1986); Dahlborn and Holtenius (1990)]. Aganga et al (1990) also stressed the importance of frequent and regular water supply to animals to meet the various needs of maintenance, pregnancy and lactation.

The total water intake of an animal includes the quantity drunk, the amount taken in as part of the foodstuffs consumed, and in addition, the water produced during the metabolism of proteins, carbohydrates and fats from absorbed dietary supplies or withdrawn from the body tissues [French (1956)]. For example, it has been observed that the metabolic oxidation of fat from the hump of an animal like the camel and the zebu cow also contribute to the water needs of these animals [French (1956)]. This water yield from the hump is small, however it contributes significantly to survival in the desert where there is a scarcity of water. Another important source of water for ruminant animals is the rumen, which is noted for serving as a large water store especially during deprivation of water [Hecker et al (1964); More and Sahni (1981); Silanikove and Tadmore (1989)].

When water is in abundant supply to ruminants, as well as other mammals, there is a close relationship between the amount of food consumed and the amount of water drunk (i.e. the turn over rate) [Leitch and Thompson (1944); Phillips (1960); Chew (1965); Johnson et al (1966); MacFarlane and Howard (1972); Silanikove (1987); Silanikove (1989)]. In one study on dairy cattle, Kay and Hobson (1963) observed that 2-4 kg of water was consumed for every kilogram of dry matter eaten.

The water requirement of animals rises during the dry season, but due to a scarcity of free water during this season, they often have to go without water for varying lenghts of time [Payne (1966)]. The increase in water need is a consequence of the insensible water loss being more pronounced through respiration, perspiration and evaporation Utley et al (1970); [More and Sahni (1981)]. The water scarcity often experienced by animals in the tropical and or semi - arid environment led to the acclimatisation and survival of desert species such as camels and Bedouin goats [Schmidt-Nielsen et al (1957); Payne (1966); More and Sahni (1981)].

It has been observed that domestic ruminants can withstand severe water deprivation [Clark and Quin (1949); French (1956); Schmidt-Nielsen et al (1957); More and Sahni (1978); Khan et al (1979); More and Sahni (1981); Silanikove (1985); Nicholson (1987)] and this can lead to reduced feed intake [More and Sahni (1972); Gihad et al (1980)]. Water restriction like water deprivation causes a reduction in feed intake and an increase in feed utilisation in various ruminant species [Balch et al (1953); French (1956); Phillips (1960); Johnson et al (1966); Thornton and Yates (1968); Bohras and Ghosh (1977); More and Sahni (1981)]. Goats are known to have higher feed utilisation efficiency than other domestic ruminants when fed a low quality diet and water restriction regimen [NRC (1975); Choshniak and Shkolnik (1978); Gihad et al (1980); Choshniak et al (1984); Silanikove

(1984); Brosh et al (1986); Brosh et al (1988)]. One can conclude that moderate water restriction is not only beneficial in terms of better feed utilisation but also of immense economic importance [French (1956); Singh et al (1976); Brosh et al (1988)].

Shkolnik and Choshniak (1984) demonstrated this economic importance in a study on Bedouin goats in the extreme deserts of the Middle East grazed on dry, low quality pasture and watered only once every 2-4 days during the prolonged dry season. While similar observations were made in domestic goats, the response of the Bedouin goats was more pronounced. Ruminants that are well adapted to a desert environment demonstrate a greater capability than non-desert breeds to ameliorate the stressful effects induced by water deprivation [Nielsen et al (1957); More and Sahni (1981); Maltz et al (1984); Schmidt- Silanikove (1992)].

Silanikove (1989) attributes this capability of the desert species to their lower metabolic rates and consequently lower water turn over (WTO) rates than domestic ruminants. According to French (1956), the metabolic water produced through oxidation of body reserves such as fat by these animals also contribute to their survival in the desert. The acclimatisation to desert environments by surviving on dew and limited moisture intake from dry plants has been documented [French (1956)]. Some desert species have the ability to replenish their entire water deficit in one short drinking bout when allowed access to water following a prolonged period of dehydration [Brosh et al (1988)]. The rumen, which acts as a water store, could also assist such animals to withstand dehydration for a long time [Silanikove and Tadmore (1989).

Other effects of water restriction on ruminants are the reduced production of urine by the kidney [English (1966)], decreased nitrogen excretion and improved nitrogen retention [Payne (1966); Topps and Elliot (1967)], as well as reduced urinary output [Livingstone et al (1962); Topps and Elliot (1967)].

Water deprivation does not significantly affect production in ruminants, as previous studies carried out have indicated that sheep deprived of water for 72 hours did not show any adverse effect on wool yield, in spite of the fact that this deprivation reduced feed intake [More and Sahni (1972)]. Earlier reports on goats maintained on a dry diet with restricted water supply show an increase in body weight of the animals. However, there was a consequent reduction in milk yield in these animals [Asdell (1950)].

From the foregoing one can deduce and even propose a strategy for ruminant production in rangeland areas. Supplying the animals with water once every 2 to 3 days has been found to be beneficial in several types of ruminants occupying desert and tropical areas [More and Sahni (1978); Khan et al (1979a,b); Musimba et al (1987); Nicholson (1987)]. It has been observed that infrequent watering intervals allow exploitation of grazing areas far from water and prevent erosion in the vicinity of water [French (1956)].

Recent findings also show that this is of relevance in areas of tropical Africa where points of water supply are scarce and grazing pressure is high [Silanikove (1992)]. Where water and food resources are limited, a saving of about 30% in water and food demands is considerable. The moderate negative effect on productive and reproductive traits of the animals would even be compensated for when there is improvement in grazing and watering conditions.

## 2.4 PHARMACOKINETICS AND GASTROINTESTINAL EFFECTS OF ATROPINE

Atropine is a lipid-soluble tertiary amine that easily penetrates the blood-brain barrier thus producing effects on the central nervous system. It is an anticholinergic drug that competitively blocks the effects of acetylcholine at the muscarinic receptor sites. It is a short-acting drug and about 50% of an injected dose appears unchanged in the urine. Another 30% are hydrolysed to inactive metabolites such as tropine and tropic acid. The loss of atropine has also been reported to occur via the plasma, especially in rabbits, which possess a specific plasma enzyme (atropine esterase) capable of hydrolysing atropine (Eger,1962).

Anticholinergic drugs inhibit cholinergic control by blocking the muscarinic receptor sites present in the heart, salivary glands and smooth muscles of the gastro -intestinal and genito-urinary tracts.There are variations in potency among anticholinergic drugs [Eger (1962)].
It has been observed that atropine has greater anticholinergic effects on bronchial smooth muscle, gastro-intestinal and genito-urinary tracts than scopolamine and some other anticholinergic drugs [Herxheimer (1958)]. The muscarinic cholinergic control caused a decrease in tone and motility of the intestine as well as inhibition of micturition [Eger (1962)]. However large doses of this drug are required to bring about these effects [Duncan (1954); Eger(1962)].

Anticholinergic drugs are antagonists of gastric hydrogen -ion secretion thus glycopyrrolate and similar drugs have been used in the management of peptic ulcer disease in human beings as they control gastric acidity [Sun (1962)]. The administered drug was in large doses similar to those used to decrease tone and motility of the gastro-intestinal tract, since the same receptor sites are being blocked [Duncan (1954); Eger (1962)].

Atropine and its contemporary tertiary amine, scopolamine, enter the central nervous system and produce central anticholinergic effects hence the use of atropine in preoperative medication especially in instances where delayed arousal from anaesthesia is desirable with the use of limited anaesthetic agent [Duvoisin and Katz (1968); Baraka et al (1980)].

Atropine sulphate administered in doses of 10-20 mg subcutaneously produced partial or complete inhibition of motility in all parts of the stomach in sheep. The effect was often more pronounced in the abomasum than that observed in the rumen or the reticulum [Duncan (1954)]. It was also reported that atropine abolished the intrinsic activity of the reticulum and rumen vagotomized sheep [Ruckebusch et al (1972); Gregory (1984)].

# CHAPTER THREE
# MATERIALS AND METHODS

## 3.1 MATERIALS

The materials used for these studies can be grouped as follows: Experimental Animals, Housing, Diet and Drug.

### 3.1.1 EXPERIMENTAL ANIMALS

| | |
|---|---|
| NUMBER OF ANIMALS | Sixteen (16) |
| SPECIES | Caprine |
| BREED | South African Pedi Goats |
| AGE | The animals were between one and a half (1½) to four (4) years of age |
| SEX | All males (to facilitate easy collection of urine) |
| BODY WEIGHT | The animals weigh between 16.2 to 41.6kg at the commencement of the trials (ca 29.1kg) |

### 3.1.2 HOUSING

The animals were housed in metabolic crates installed in two rooms, the temperature of which was regulated to simulate the natural environment in which the goats were reared. The metabolic crates have facilities for feeding and watering the animals individually. There were also provisions for the separate collection of urine and faeces from each animal within the crates.

### 3.1.3 DIET AND DRUG

The animals were fed with a diet prepared from lucerne (*Medicago sativa)* and eragrostis hay (*Eragrostis curvula*) which on analysis contained 13.57% and 4.68% crude protein respectively. Molasses was also added to the lucerne/eragrostis mixture at the rate of 8kg per 250kg feed in order to bind the components and reduce dust. After milling the diet was physically as uniform as possible with a particle size ranging from 0.5 to 2cm in length. The two components were mixed to obtain final values of 10.5% crude protein, 38% crude fibre (39% ADF, 71% NDF) and 17.5 MJ/kg gross energy on a dry matter (DM) basis.

**Figure 1:***Typical metabolic crate housing a goat during the trial*

The Atropine(R)* used during the course of the experiment was atropine sulphate, injected subcutaneously.

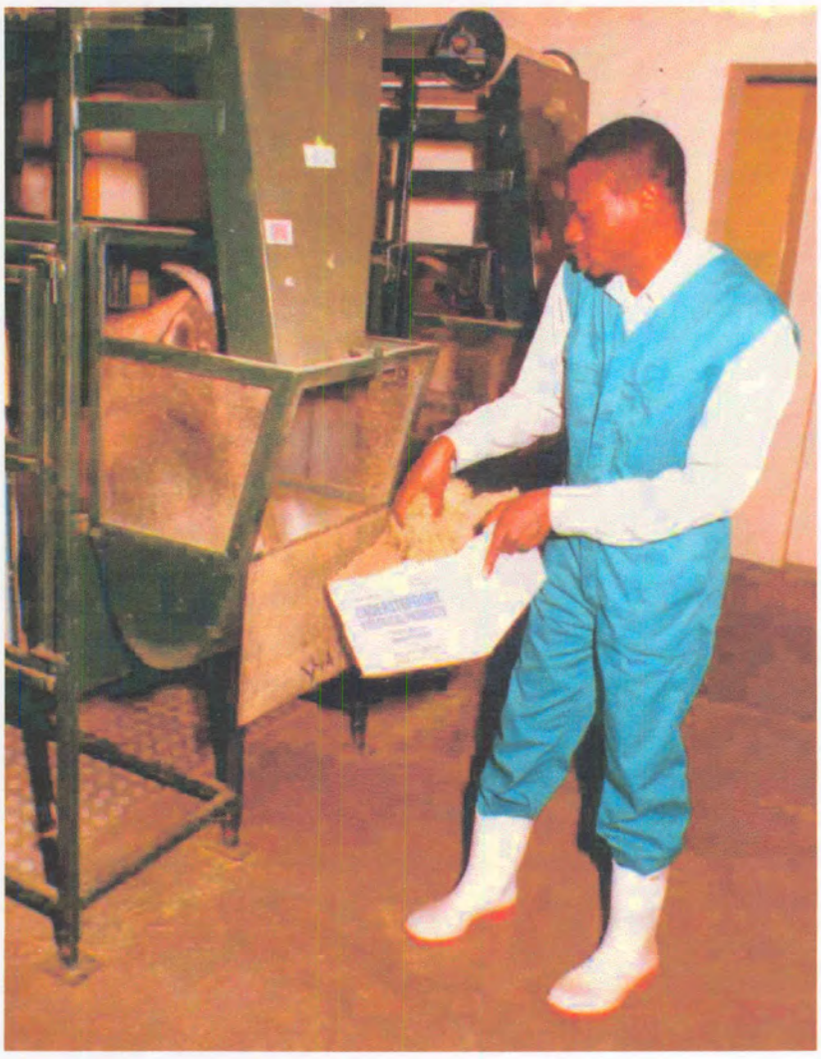

**Figure 2:** *The investigator feeding one of the experimental goats*

## 3.2 METHODS

These studies were conducted at Onderstepoort for six (6) weeks during the cold months of June to August 1999 (winter). Experimental procedures included two trials of water restriction and water deprivation, including the later use of the drug.

*Bayer Animal Health (Pty) Ltd
27 Wrench Road, Isando 1600, South Africa

### 3.2.1 MANAGEMENT

The goats were housed individually in metabolic crates that were numbered according to the goats' identification numbers. The goats were accustomed to the crates for nine (9) days prior the trials. During this period, the animals were fed *ad libitum* with 1000 or 1300g of the diet (depending on body weight) and provided with 5000ml clean drinking water every morning.

The feed and water intakes were measured and recorded daily during this adaptation period. These intakes were used to determine average values for each animal. The animals were weighed before and after every trial and clinically examined daily.

Blood samples were collected from a jugular vein of each goat at least twice in each trial, in particular before and after water restriction or water deprivation. The haematocrit or packed cell volume (PCV), total plasma protein (TPP) and osmolarity of the blood was determined from these samples for each goat.

The physiological values (PCV,TPP and osmolarity) were used in conjunction with the clinical parameters and body weight assessment to monitor the hydration status of the animals throughout the course of the experiment. The animals were also rehydrated for four (4) days in between the trials in order to limit the stress imposed on them by water restriction and /or water deprivation.

### 3.2.2 EXPERIMENTAL PROCEDURE

The experiment broadly entails two trials: Water restriction and Water deprivation plus atropine administration.

#### 3.2.2.1 TRIAL 1 - WATER RESTRICTION

Only fifteen (15) of the goats were used for this trial. The goats were divided into three groups of five animals each after adaptation to diet and stabilisation in the crates. There were three classes based on body weight as shown in Appendix 5 (<25kg, 25-35kg, >35kg) and were equally represented in all the groups. Thus all the three groups were similar and could be compared to one another. All the goats in each group were fed *ad libitum*. Each received 1000 or 1300g of the diet depending on body weight. The younger ones of about 25kg and below were given 1000g while older goats weighing above 25kg received 1300g of the diet. This amount exceeded the daily intake to allow actual consumption to be measured.

The animals were subjected to three different levels of watering regimen, according to their grouping. The water intake of one group was restricted to 30% of their *ad libitum* intake according to the values calculated from the mean of their daily intake over the adaptation period. The values were corrected for evaporation, measured from a container kept in the same room as the goats, and similar to the water troughs used by the goats. Another group of animals were given 50% of their *ad libitum* water intake, based on the same procedure as described above for the 30% group. A third group was offered water *ad libitum* (5000 ml daily) and serve as a control group during the experiment.

During this trial, the feed and water intakes of each animal were measured daily. The feed residues were weighed every morning prior to providing fresh feed. Water residues were measured in a measuring cylinder before offering the daily ration.

**Figure 3:***A goat being watered ad libitum to serve as control*

The urine and faecal outputs of each animal in all 3 groups were also measured by weighing the faeces and measuring the volume of the urine produced using a graduated cylinder.

This trial was conducted over a period of 8 days, after which the animals were allowed to rehydrate by given them clean drinking water (5000 ml) *ad libitum* for a period of 4 days prior to the second phase of the experiment.

### 3.2.2.2 TRIAL 2 - WATER DEPRIVATION AND ATROPINE ADMINISTRATION

This trial involved sixteen (16) goats which were randomly divided into two groups of 8 animals each. During phase one, one group was deprived of water for 2 days and allowed *ad libitum* access to water every 3rd day for a maximum period of 4 hours (between 8:00 and 12 :00). This protocol was chosen to simulate natural conditions of water scarcity occuring in arid regions of Africa, whereby animals are deprived of water for long periods of time, drinking only occasionally when water becomes available. On the other hand, animals in the other group received water *ad libitum* daily to serve as control. Both groups were fed the lucerne/eragrostis diet *ad libitum* on a daily basis.

Each group was further divided into two subgroups, such that half of each group was scheduled to receive atropine. On day 8 of phase one, which coincided with water deprivation for the treatment group, the subgroups were injected subcutaneously with atropine at a dose rate of 0.04 mg per kg body weight. The remaining 8 animals were injected with atropine on day 11, which resulted in previously untreated animals being dosed with atropine as described above. This procedure facilitates the grouping of the animals into four subgroups of 4 animals each for the following treatments: atropine administration to water deprived goats; water deprivation without atropine administration; atropine administration to goats on *ad libitum* water regimen; goats on *ad libitum* water regimen without atropine administration. All the animals also received the four treatments thus each goat served as its own control.

The feed and water intakes as well as faeces and urine outputs were measured daily during the trial. In addition, faeces and urine outputs

were measured at 4-hour intervals for 12 hours on the day of atropine administration. Thus, on days 8 and 11 of this trial, faeces and urine outputs were measured at 09:00, 13:00, 17:00 and 21:00 in order to follow the effects of this drug on the animals.

During the second phase of the trial, which also took 15 days, water was now given *ad libitum* to the group that had been deprived while the group that had been given *ad libitum* access to water now became the treatment group, and were watered every fifth day. The procedures of atropine injection, measurement of feed and water intakes was repeated as for phase one. Similarly, the production of faeces and urine were monitored and recorded on a daily basis as for phase one.

### 3.2.3 SAMPLE COLLECTION, STORAGE AND ANALYSIS

In the water restriction trial, daily samples were taken from the faeces and urine produced for 8 days, preserved in sealed plastic bags and test tubes respectively and stored in a refrigerator for further analysis.

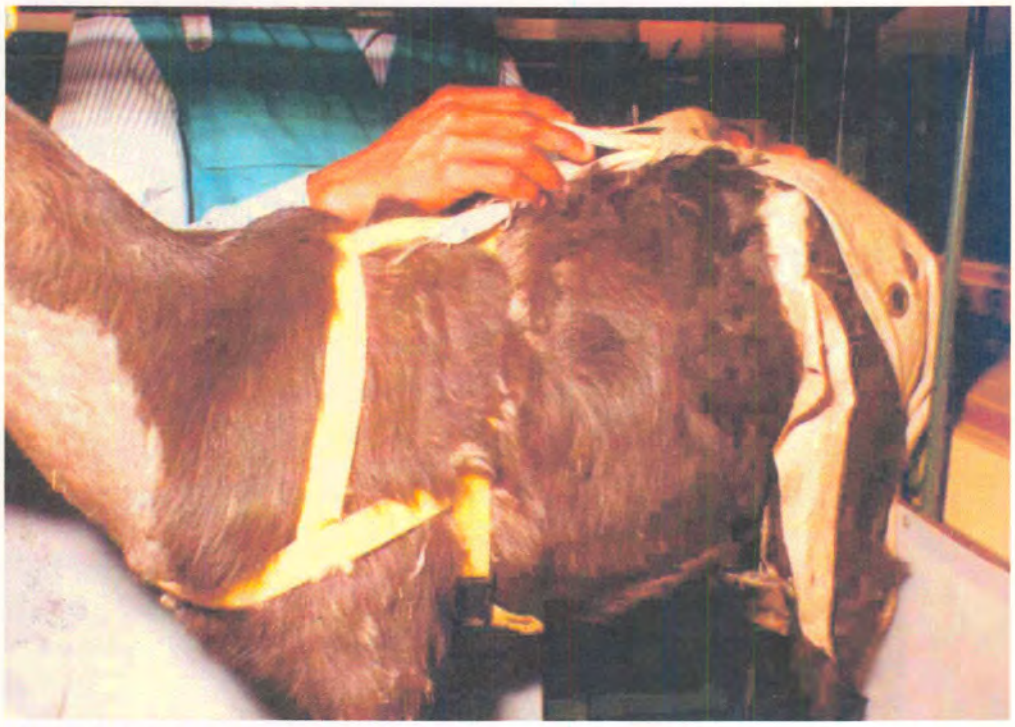

**Figure 4:** *The faecal bag is being tied on a goat to collect the faeces*

Similar samples were collected during the second trial (water deprivation) for 8 days, starting from the day of atropine injection till the end of each phase of the trial. Samples were taken four times on every day of the drug administration, i.e. 9:00, 13:00, 17:00 and 21:00 hours.

The neck region of each goat was shaved and jugular blood samples were aseptically collected into vacuum tubes containing heparin one hour before and an hour after atropine injection. The blood samples were analysed for PCV, TPP and osmolarity and the plasma separated and stored at $-20^0$C for further analysis.

The urine and faecal samples were later defrosted and analysed according to standard procedures (AOAC, 1984). The faeces were analysed for moisture, organic matter, acid detergent fibre (ADF), neutral detergent fibre (NDF), nitrogen and protein while the urea content of the urine and plasma was determined.

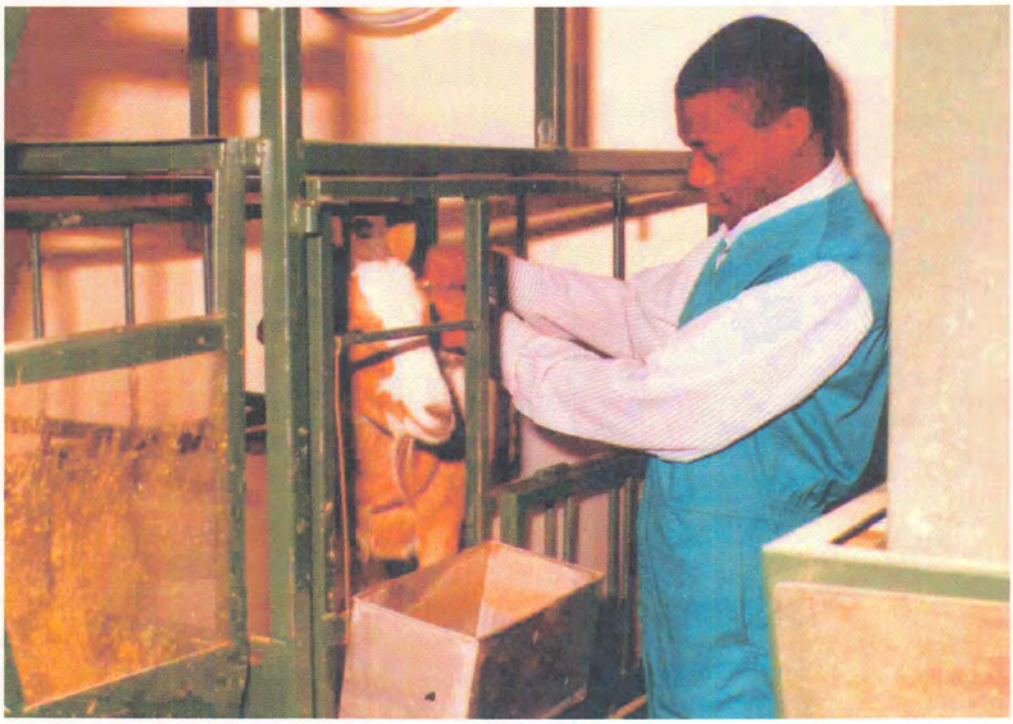

**Figure 5:** *The investigator securing the faecal bag to the harness of a goat*

A Leco Analyser designed by FP-428 Nitrogen and Protein Determinator (Leco Inc.,USA) was used to determine nitrogen and protein digestibility. ADF was analysed using the acid detergent solution described by Goering and van Soest (1970).

The results of nitrogen utilisation by the goats in both trials were obtained through the analyses of feed, faeces and urine. A representative sample of the diet fed to the goats during the trial periods was obtained for the feed analysis. A pool of faecal samples collected during the restriction and deprivation periods was used while urine analysis was performed on several subsamples and calculating the average to reflect trial periods (restriction and deprivation). The raw data obtained for individual animals are presented in Appendix 6.

The plasma was defrosted for the analysis of atropine and its metabolites with a method designed by Dr S Bye of BSC Company (Pietermaritzburg).

On completion of the trials, the experimental goats were returned in good health to an outside camp and under the care of the Department of Veterinary Physiology, University of Pretoria (Figure 6).

**Figure 6:** *Goats at completion of the trial*

### 3.2.4 STATISTICAL ANALYSIS

The results are presented as means ± S.D (standard deviation). A paired Student's t-test was used to assess the significance of differences between values recorded for treatment and control groups in both trials. A value of $P < 0.05$ was accepted as significant in all cases.

The data were analysed to establish the effect of body weight on the grouping of the goats. The data have also been presented per kilogram body weight to eliminate any obvious influences. The body weight did not have a significant effect within the groups.

# CHAPTER FOUR
# RESULTS

All the results presented were for two trials. Trial 1 refers to the goats when water was restricted, while during trial 2 the treatment groups were deprived of water for either 3 or 5 days with concurrent administration of atropine.

## 4.1 FEED INTAKE

In trial 1, increasing the degree of water restriction reduced the feed Intake, although only the group receiving 30% of their *ad libitum* water intake were significantly lower than control values (Table 1). However the calculation of the feed to water ratio showed that the restricted goats consumed more feed per unit litre of water than the control group.

In trial 2, depriving the goats of water produced similar results to the restriction trial. However, while the group getting water only every fifth day consumed significantly less feed than the control group, their feed intake was not different to that of the group getting water every third day (Table 2). There was an increasing trend in feed consumption relative to water intake by water deprived goats similar to that observed when the goats were on water restriction.

## 4.2 WATER CONSUMPTION

The results in Table 1 show that there was a significant difference in the water intake among the 3 groups during trial. When the water consumption was calculated in $ml/kgW^{0.75}$, the average reduction in water intake by the groups reflect the level of water restriction as shown in Table 1.

**Table 1:** Water and feed intake of goats on water restriction (means ± S D).

| Trial 1 | Control | Treatment | |
|---|---|---|---|
| | Free choice water | 50% of free choice water | 30% of free choice water |
| Water Intake* (L/d) | 1.43 ± 0.37[a] | 0.65 ± 0.09[b] | 0.33 ± 0.00[c] |
| Water consumed (ml/kgW$^{0.75}$) | 112.0 ± 31.0[a] | 55.5 ± 15.8[b] | 0.61 ± 0.10[c] |
| Feed intake* (Kg/d) | 0.76 ± 0.16[a] | 0.64 ± 0.09[a] | 0.54 ± 0.08[b] |
| DMI (g/kgW$^{0.75}$) | 53.92 ± 6.07[a] | 49.08 ± 5.41[a] | 41.25 ± 7.21[b] |
| Feed to water (Kg/L) | 0.55 ± 0.09 | 1.00 ± 0.22 | 1.65 ± 0.28 |

Superscripts that differ on the same line denote values that are different at the $P<0.05$ level.

*Raw data shown in Appendix 1

**Table 2**: Water and feed intake of goats on water deprivation (means ±S.D).

Trial 2 Water Regimen

| | Daily | Once in 3 days | Once in 5 days |
|---|---|---|---|
| Water Intake* (L/d) | $1.47 \pm 0.34^{a}$ | $0.84 \pm 0.20^{b}$ | $0.54 \pm 0.13^{c}$ |
| Water consumed ($ml/kgW^{0.75}$) | $118.5 \pm 25.7$ | $68.7 \pm 16.2$ | $44.6 \pm 10.2$ |
| Feed intake (Kg/d) | $0.93 \pm 0.12^{a}$ | $0.80 \pm 0.14^{a,b}$ | $0.78 \pm 0.13^{b}$ |
| DMI ($g/kgW^{0.75}$) | $70.30 \pm 10.05$ | $62.48 \pm 6.12$ | $48.42 \pm 14.13$ |
| Feed to water (Kg/L) | $0.65 \pm 0.12$ | $0.98 \pm 0.28$ | $1.47 \pm 0.19$ |

Superscripts that differ on the same line denote values that are statistically different at the $P<0.05$ level.

*Raw data shown in Appendix 1

In the second trial, the average *ad libitum* water intake by the control group was 1.47L . The water deprived groups consumed 2.53L and 2.71L once in 3 days and 5 days on average respectively. When these figures were calculated as an average daily water intake, the respective values were 0.84L and 0.54L for the 3-day and 5-day groups respectively (Table 2).

These values were significantly lower than the average daily water intake by the control group. The reduction in water consumption (ml/kgW$^{0.75}$) by the water deprived goats show a similar pattern to the observation made in trial 1.

## 4.3 NUTRIENTS DIGESTIBILITY

Tables 3 and 4 show the average daily intake, digestible intake and digestibility coefficients of nutrients by the goats in both trials.

### 4.3.1 DRY MATTER

In the 1$^{st}$ trial, 701.02g of dry matter was consumed daily on average by the goats on free choice water (control). This amount was higher than the average dry matter intake by the 50% group (592.91g), and significantly higher than the average intake by the 30% group (494.91) as shown in Table 3 (raw data shown in Appendix 2). A decreasing trend in intake was shown by both restricted groups.

The restricted groups (50% and 30% water intake) digested the dry matter taken in slightly better than the control group (*ad libitum* group), with 30% group showing the highest average digestibility coefficient for the feed. However there was no significant difference in the digestibility of the feed by the 3 groups during this trial.

**Table 3:** Daily intake, digestible intake and digestibility coefficient of nutrients by goats on water restriction (means±SD).

| Trial 1 | Control | Treatment | |
|---|---|---|---|
| | Free choice water | 50% of free choice water | 30% of free choice water |
| **DM** | | | |
| Intake (g/d) | 701.02 ± 172.92[a] | 592.91 ± 197.05[a] | 494.91 ± 192.46[b] |
| Digestible (g/d) | 408.36 ± 110.41 | 344.43 ± 56.51 | 268.82 ± 81.79 |
| Digestibility (%) | 58.0 ± 2.1[a] | 58.1 ± 17.1[a] | 59.2 ± 16.7[a] |
| **CP** | | | |
| Intake (g/d) | 79.71 ± 19.66[a] | 67.42 ± 22.41[a] | 56.27 ± 21.88[b] |
| Digestible (g/d) | 30.80 ± 8.97 | 23.84 ± 9.24 | 26.89 ± 6.16 |
| Digestibility (%) | 38.5 ± 6.9[a] | 35.4 ± 12.4[a] | 47.7 ± 13.6[b] |
| **ADF** | | | |
| Intake (g/d) | 298.44 ± 73.61[a] | 252.41 ± 83.89[a] | 210.69 ± 81.94[b] |
| Digestible (g/d) | 151.88 ± 38.18 | 125.95 ± 39.46 | 129.27 ± 26.58 |
| Digestibility (%) | 50.9 ± 5.8[a] | 49.7 ± 15.5[a,b] | 61.3 ± 16.8[b] |

Superscripts that differ on the same line denote values that are statistically different at the $P<0.05$ level.

In the 2nd trial (Table 4), the amount of dry matter taken in by the control group) was significantly higher (847.69 g/d) than the amount consumed by the 5-day group (611.45 g/d), and slightly higher than the average intake by the 3-day group (794.39 g/d).

In this trial the feed digestibility by the control group was significantly higher than that of the group given water once in 5 days (62.3% vs 55.3%). However, there was no difference between the control group and the goats watered once in 3 days, and both treatment groups did not differ in feed digestibility as well (Table 4).

### 4.3.2 PROTEIN

As expected the average intake of crude protein (CP) by all the three groups followed the same trend as that of dry matter intake (DMI) in trial 1. This is because CP intake is a function of DMI.

The results show that the digestibility coefficient of the protein in the diet for the 30% group was significantly higher than those for the control group and the 50% group (Table 3). There was no difference between the control group and the 50% group in CP digestibility. Raw data is shown in Appendix 2.

**Table 4:** Daily intake, digestible intake and digestibility coefficient of nutrients by goats on water deprivation (means ± SD).

Trial 2 Water Regimen

| | Daily | Once in 3 days | Once in 5 days |
|---|---|---|---|
| **DM** | | | |
| Intake (g/d) | 847.69 ± 128.83[a] | 794.39 ± 174.62[a] | 611.45 ± 183.76[b] |
| Digestible (g/d) | 527.82 ± 90.73 | 469.31 ± 113.67 | 346.89 ± 124.70 |
| Digestibility (%) | 62.3 ± 4.7[a] | 59.5 ± 8.5[a,b] | 55.3 ± 7.0[b] |
| **CP** | | | |
| Intake (g/d) | 96.38 ± 14.65[a] | 90.25 ± 19.85[a] | 69.53 ± 20.90[b] |
| Digestible (g/d) | 36.85 ± 14.49 | 40.52 ± 12.06 | 45.26 ± 21.29 |
| Digestibility (%) | 37.9 ± 11.9[a] | 44.4 ± 5.4[a,b] | 49.1 ± 3.9[b] |
| **ADF** | | | |
| Intake (g/d) | 360.88 ± 54.85[a] | 338.19 ± 74.34[a] | 260.31 ± 78.23[b] |
| Digestible (g/d) | 165.97 ± 36.36 | 175.34 ± 61.97 | 128.60 ± 50.46 |
| Digestibility (%) | 45.9 ± 6.3[a] | 51.1 ± 10.0[a] | 48.2 ± 8.8[a] |

Superscripts that differ on the same line denote values that are statistically different at the $P<0.05$ level.

In the 2nd trial, the trend in crude protein consumption was similar to DMI for all groups (Table 4).

The 5-day water deprivation group digested the CP significantly better than the control group but did not show any difference compared to the 3-day water deprivation group. The latter (3-day group) did not differ from the control group as well (Table 4).

### 4.3.3 FIBRE

The procedure used for neutral detergent fibre (NDF) analysis was not reliable hence results were not presented.

In trial 1, the results of ADF intake (Table 3) showed the same trend as dry matter intake (DMI).

The results showed that the 30% group digested the fibre more efficiently than the control group. The higher ADF consumption by the 50% group did not reflect any difference in the fibre digestion by this group compared to the 30% group. Table 3 also show that there was no difference in the digestibility coefficient of the 50% group compared to that of the control group.

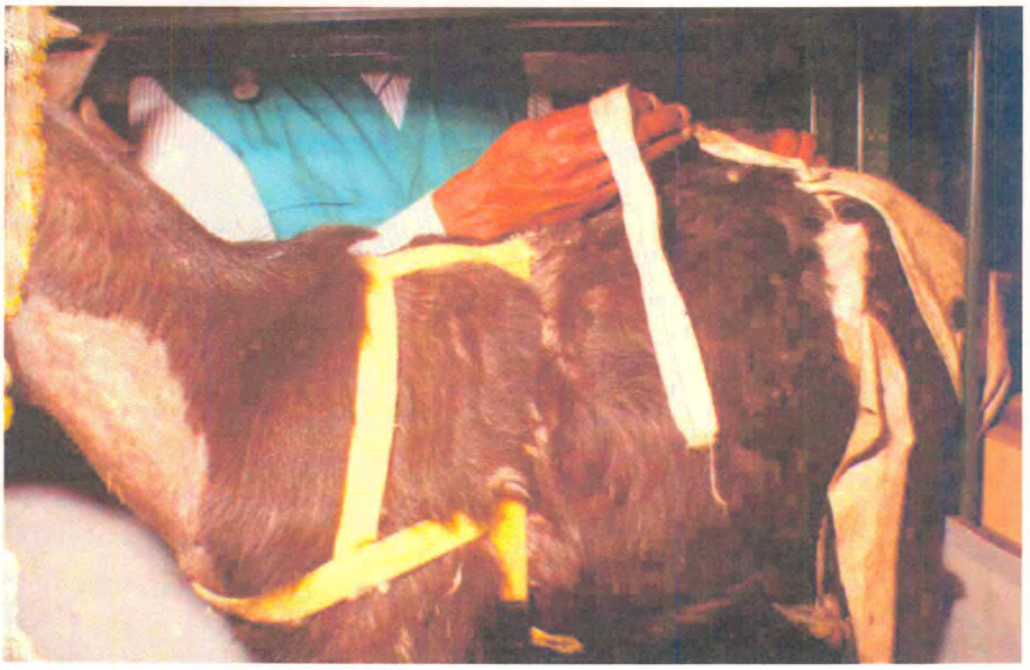

**Figure 7:** *Removal of faecal bag to collect and weigh the faeces*

Results of ADF intake and digestibility by the goats during the 2nd trial are shown in Table 4. The consumption followed the same trend as DMI.

Despite the higher amount of ADF intake by the control and the 3-day groups, there was no significant difference in fibre digestion between any of the 3 groups of animals during this trial.

## 4.4 URINE OUTPUT

In the 1st trial, the average volume of urine lost by the experimental animals is shown in Table 5 (Raw data listed in Appendix 3). The average volumes of urine produced, as calculated from these raw data, were found to be 0.36L/d (100% water intake), 0.21L/d (50% water intake) and 0.22L/d (30% water intake). On average, the goats allowed water *ad libitum* (control group) lost more urine than the water-restricted groups.

**Figure 8:** *The investigator measuring urine output of experimental goat*

Results of the analysis on the urine produced by the animals during the 2nd trial are tabulated in Table 7 and Appendix 3.

It was observed that the average volume of urine lost by the goats given water *ad libitum* daily was the highest (0.42L/d). The other 2 groups produced 0.24L/d (3–day water deprivation) and 0.23L/d (5–day water deprivation).

The deviation from the control in the average urine outputs of both treatment groups was insignificant.

## 4.5 UREA PRODUCTION

The concentration and quantity of urea lost via the urine by the experimental goats in both trials are shown in Tables 5 and 6 (Raw data is listed in Appendix 3).

When the animals were subjected to the water restriction trial, the urea produced by the control group was 249.0 mmol/d with an average concentration of 524.28 mmol/L as shown in Table 5.

The treatment groups produced less urea [82.9 mmol/d (50% group) and 82.6 mmol/d (30% group)] than the control group (Table 5).

The urea concentration of these 2 groups was found to be 404.04mmol/L and 365.90 mmol/L for the 50% and 30% water intake groups respectively.

In the 2nd trial, the average urea output shown in Table 6 was - control group : 164.6 mmol/d with 410.36 mmol/L concentration; 3-day group : 136.9 mmol/d with 589.64 mmol/L concentration; and 5-day group : 117.0 mmol/d with 526.78 mmol/L concentration.

The average urea output by each of the treatment groups was found to be significantly less than the amount lost by the control group.

**Table 5:** Urine and urea outputs of goats on water restriction (means ± SD).

| Trial 1 | Control | Treatment | |
|---|---|---|---|
| | Free choice water | 50% of free choice water | 30% of free choice water |
| Urine output (L/d) | 0.36 ± 0.36 | 0.21 ± 0.09 | 0.22 ± 0.08 |
| Urea output (mmol/d) | 249.0 ± 394.7 | 82.9 ± 34.2 | 82.6 ± 37.8 |
| Urea conc (mmol/L) | 524.28 ± 281.7 | 404.04 ± 72.8 | 365.90 ± 45.6 |

**Table 6:** Urine and urea outputs of goats on water deprivation (means ± SD).

| Trial 2 | Water Regimen | | |
|---|---|---|---|
| | Daily | Once in 3 Days | Once in 5 Days |
| Urine output (L/d) | 0.42 ± 0.12 | 0.24 ± 0.11 | 0.23 ± 0.08 |
| Urea output (mmol/d) | 164.6 ± 58.6 | 136.9 ± 60.4 | 117.0 ± 41.4 |
| Urea conc (mmol/L) | 410.36 ± 156.2 | 589.64 ± 199.9 | 526.78 ± 139.2 |

## 4.6 USE OF WATER

The results of the total water intake, output and the water efficiency by the experimental goats in both trials are shown in Tables 7, 8, 9 and 10. The insensible loss is the water used by the animals for metabolism and that lost through respiration, perspiration and evaporation.

In the 1st trial, restricting the water intake of the goats produced significant differences in water consumption among the 3 groups as shown in Table 7. However, the volume of water consumed through the feed intake by the 50% group was insignificant compared to the amount taken in by the control group via this medium (Table 7). This is a function of DMI which had been discussed in detail earlier. Due to the negative effect of water restriction on DMI, the contribution by feed water to total water intake was significantly different between all the three groups.

The results shown in Table 7 indicate that both treatment groups lost more water through the faeces and urine thus 89.2% and 64.3% by the 30% and 50% groups respectively compared to 42.3% lost by the control group through the same excretory routes. The restriction of water intake of the goats to 50% led to a higher faecal water loss (34.3%) compared to that of the control (18.1%). Further restriction to 30% of daily water intake produced a corresponding reduction in the percentage (29.7%) of water lost through the faeces by this group (30% group) relative to the 50% group (Table 7).

The volume of water used by the goats on *ad libitum* water intake (control group) for metabolism and other uses on average was 0.86L/d. This amount was more than that of the other 2 groups which were 0.26L/d and 0.04L/d for 50% and 30% water intake groups respectively.

**Table 7:** Water balance by goats on water restriction (means ± SD).

Trial 1 Control Treatment

| | Free choice water | 50% free choice water | 30% free choice water |
|---|---|---|---|
| **Intake** | | | |
| Free water (L/d) | 1.43 ± 0.37[a] | 0.65 ± 0.09[b] | 0.33 ± 0.00[c] |
| % of total intake | 96.0 | 92.9 | 89.2 |
| Feed water (L/d) | 0.06 ± 0.013[a] | 0.05 ± 0.008[a] | 0.04 ± 0.008[b] |
| % of total intake | 4.0 | 7.1 | 10.8 |
| Total water (L/d) | 1.49 ± 0.43[a] | 0.70 ± 0.10[b] | 0.37 ± 0.02[c] |
| **Output** | | | |
| Faeces (kgDM/d) | 0.29 ± 0.06[a] | 0.25 ± 0.05[a,b] | 0.20 ± 0.04[b] |
| Faecal water (%) | 46.8 | 47.5 | 34.5 |
| Faecal water (L/d) | 0.27 ± 0.09[a] | 0.24 ± 0.09[a] | 0.11 ± 0.03[b] |
| % of total intake | 18.1 | 34.3 | 29.7 |
| Urine (L/d) | 0.36 ± 0.36[a] | 0.21 ± 0.09[b] | 0.22 ± 0.08[b] |
| % of total intake | 24.2 | 30.0 | 59.5 |
| Insensible loss (L/d) | 0.86 ± 0.11[a] | 0.26 ± 0.16[b] | 0.04 ± 0.09[c] |
| % of total intake | 57.8 | 35.7 | 10.8 |
| Total water (L/d) | 1.49 ± 0.43[a] | 0.71 ± 0.10[b] | 0.37 ± 0.02[c] |

Superscripts that differ on the same line denote values that are statistically different at the $P<0.05$ level.

**Table 8**: Water efficiency of goats on water restriction (means ± SD).

| Trial 1 | Control | Treatment | |
|---|---|---|---|
| | Free choice water | 50% free choice water | 30% free choice water |
| Body weight (kg) | 30.6 ± 8.3 | 28.8 ± 8.3 | 29.7 ± 11.0 |
| Water intake (L/d) | 1.43 ± 0.37[a] | 0.65 ± 0.09[b] | 0.33 ± 0.00[c] |
| Water consumed (L/kg feed intake) | 1.88 ± 0.33[a] | 1.02 ± 0.17[b] | 0.61 ± 0.10[c] |
| Water efficiency (ml/kg$^{0.75}$/day) | 112.0 ± 31.0[a] | 55.5 ± 15.8[b] | 28.1 ± 10.3[c] |

Superscripts that differ on the same line denote values that are statistically different at the $P<0.05$ level.

The ratio of water consumed to feed intake by the goats during this trial as presented in Table 8 show significant differences among the 3 groups. Table 8 also shows the calculations of water efficiency in ascending order of efficiency thus: control group (112.0 ml/kg$^{0.75}$/day), 50% group (55.5 ml/kg$^{0.75}$/day) and 30% group (28.1 ml/kg$^{0.75}$/ day). This is a reflection of the water restriction treatment given to these groups.

The results of water consumption by the experimental goats during water deprivation trial were similar to those obtained in the first trial (water restriction) in that it reflects the different treatments.

The volume of the free water intake by the 3 groups were different from one another as shown in Table 9.

**Table 9:** Water balance by goats on water deprivation (means ± SD).

Trial 2 Water Regimen

| | Daily | Once in 3 Days | Once in 5 Days |
|---|---|---|---|
| **Intake** | | | |
| Free water (L/d) | 1.47± 0.34[a] | 0.84 ± 0.20[b] | 0.54 ± 0.13[c] |
| % of total intake | 95.5 | 93.3 | 90.0 |
| Feed water (L/d) | 0.07 ± 0.009[a] | 0.06 ± 0.014[a] | 0.06 ± 0.013[b] |
| % of total intake | 4.5 | 6.7 | 10.0 |
| Total water (L/d) | 1.54 ± 0.37[a] | 0.90 ± 0.21[b] | 0.60 ± 0.15[c] |
| **Output** | | | |
| Faeces (kgDM/d) | 0.32 ± 0.06[a] | 0.31 ± 0.07[a,b] | 0.27 ± 0.07[b] |
| Faecal water (%) | 58.2 | 51.9 | 45.3 |
| Faecal water (L/d) | 0.45 ± 0.10[a] | 0.33 ± 0.10[a] | 0.23 ± 0.08[b] |
| % of total intake | 29.2 | 36.7 | 38.3 |
| Urine (L/d) | 0.42 ± 0.12[a] | 0.24 ± 0.11[b] | 0.23 ± 0.08[b] |
| % of total intake | 27.3 | 26.7 | 38.3 |
| Insensible loss (L/d) | 0.68 ± 0.31[a] | 0.33 ± 0.12[b] | 0.15 ± 0.07[c] |
| % of total intake | 43.5 | 36.7 | 23.3 |
| Total water (L/d) | 1.55 ± 0.37[a] | 0.90 ± 0.21[b] | 0.61 ± 0.15[c] |

Superscripts that differ on the same line denote values that are statistically different at the $P<0.05$ level.

There was also a difference in the water intake via the feed by the 5-day group compared to that by the control group. The volume of feed water consumed by the latter (control group) was insignificant relative to the value obtained for the 3-day group ( Table 9).

Table 9 show the average daily faecal water loss by the goats during water deprivation. When these data were calculated, the average faecal water loss by the control group was significantly different from that lost by each of the treatment groups (Table 9). In addition, both the control and the 3-day groups prevented additional water loss by reducing urine output (26.7% and 27.3%) as compared to the significantly higher percentage of urine lost by the 5-day group (38.3%).

**Table 10:** Water efficiency of goats on water deprivation (means ± SD).

Trial 2 Water Regimen

| | Daily | Once in 3 days | Once in 5 days |
|---|---|---|---|
| Body weight (kg) | 29.8 ± 8.9 | 28.7 ± 6.7 | 28.8 ± 9.4 |
| Water intake (L/d) | 1.47 ± 0.34$^{a}$ | 0.84 ± 0.20$^{b}$ | 0.54 ± 0.13$^{c}$ |
| Water consumed (L/kg feed intake) | 1.58 ± 0.27$^{a}$ | 1.05 ± 0.17$^{b}$ | 0.69 ± 0.04$^{c}$ |
| Water efficiency (ml/kg$^{0.75}$/day) | 118.5 ± 25.7$^{a}$ | 68.7 ± 16.2$^{b}$ | 44.6 ± 10.2$^{c}$ |

Superscripts that differ on the same line denote values that are statistically different at the $P<0.05$ level.

The results shown in table 9 also indicate that the volume of insensible water lost by the control group was more than the amount lost by each of the treatment groups. The 5–day group used the smallest amount of water for metabolism and other needs (insensible loss).

During water deprivation, the water consumed (L/kg feed intake) by the control group was more than the volume consumed by each of the treatment groups (Table 10). The calculations of water efficiency (ml/kg$^{0.75}$/day) as shown in Table 10 are 118.5 ( control group), 68.7 (3-day deprivation group) and 44.6 (5-day deprivation group), a reflection of higher efficiency by the treatment groups.

## 4.7 BODY WEIGHT VARIATION

The average estimated values of body weight variation of the experimental goats in both trials are shown in Tables 8 and 10 (Raw data is listed in Appendix 5).

During the water restriction trial, there was a decrease in the average body weight by the goats on *ad libitum* water regimen (control group). On the average, the restricted goats gained weight during the trial. The average increase in weight by these 2 groups were 0.4kg (28.8 - 28.4kg) and 0.8 kg (29.7 - 28.9kg) for the 50% and 30% groups respectively .

In the second trial, this trend was reversed. The goats on the *ad libitum* daily water intake (control group) increased their body weights from 29.2 kg to 29.8 kg on the average (Appendix 5). The average body weight of the 3-day water deprivation group was 29.8 kg and decreased to 28.7 kg while that of the 5-day water deprivation group reduced from 29.2 kg to 28.8 kg.

The loss in body weight by the goats during both trials was consequently compensated for on rehydration within a few days. This

was shown by the final body weights of the animals on completion of the trials (data not shown).

## 4.8 NITROGEN METABOLISM

When the nitrogen utilisation data was calculated for the water restricted goats (trial 1), it was found that 12.75g of nitrogen was consumed on the average by the control group. This amount was significantly higher than N-intake by the 30% group (9.00g), and slightly, albeit insignificantly higher than that by the 50% group (10.79g) as shown in Table 11.

There was no difference in the amount of nitrogen lost via the faeces by the 50% group relative to that by the control group, while the 30% group excreted less nitrogen through the faeces than the control group (Table 11). Table 11 also show that both treatment groups conserve more nitrogen than the control group, as they (treatment groups) excreted less nitrogen via the urine than the latter (control group).

The quantity of nitrogen retained was obtained by subtracting the total amount excreted from that consumed. The control group had a deficit N retention (-0.30 g/d). The 50% and 30% groups retained significantly higher amount of nitrogen than the control group (Table 11).

**Table 11:** Daily nitrogen consumption, excretion and retention by goats on water restriction (means ±S.D).

| Trial 1 | Control | Treatment | |
|---|---|---|---|
| | Free choice water | 50% free choice water | 30% free choice water |
| **Intake** | | | |
| N consumed (g/d) | 12.75 ± 3.15[a] | 10.79 ± 1.71[a] | 9.00 ± 1.65[b] |
| **Excretion** | | | |
| Faecal N (g/d) | 7.83 ± 2.04[a] | 6.97 ± 1.62[a] | 4.40 ± 1.10[b] |
| % of N consumed | 61.4 | 64.6 | 48.9 |
| Urine N (g/d) | 5.23 ± 8.29[a] | 1.74 ± 0.72[b] | 1.73 ± 0.78[b] |
| % of N consumed | 41.0 | 16.1 | 19.2 |
| **Retention** | | | |
| Intake – excretion (g/d) | - 0.30 ± 7.28[a] | 2.08 ± 1.52[b] | 2.87 ± 0.80[b] |
| % of N consumed | - 2.4 | 19.3 | 31.9 |

Superscripts that differ on the same line denote values that are statistically different at $P<0.05$ level.

The results of the daily nitrogen balance for each goat during the 2nd trial are shown in Appendix 6. When these data were calculated, the results obtained as presented in Table 12 show that the average daily nitrogen intake by the 5-day group was significantly lower than the N-intake by the 3-day and control groups. The latter (3-day and control groups) did not differ in N-intake.

There was difference in the amount of faecal nitrogen loss among the 3 groups. The results of urine analysis showed that the 5-day group lost significantly less nitrogen than the control group, while the amount lost by the 3-day group did not attain any significance relative to that lost by

the control group (Table 12). There was also no difference in the amount of nitrogen lost via the urine by both treatment groups.

Table 12 also show that the control group retained an average of 1.73g nitrogen per day, which was significantly less than the amount retained by the treatment groups.

**Table 12:** Daily nitrogen consumption, excretion and retention by the goats on water deprivation (means ±SD).

Trial 2 Water Regimen

| | Daily | Once in 3 Days | Once in 5 Days |
|---|---|---|---|
| **Intake** | | | |
| N consumed (g/d) | 15.42 ± 2.34[a] | 14.45± 3.18[a] | 11.13 ± 3.34[b] |
| **Excretion** | | | |
| Faecal N (g/d) | 10.22 ± 1.70[a] | 7.97 ± 1.55[b] | 5.62 ± 1.62[c] |
| % of N consumed | 66.3 | 55.2 | 50.5 |
| Urine N (g/d) | 3.46 ± 1.23[a] | 2.78 ± 1.37[a,b] | 2.46 ± 0.87[b] |
| % of N consumed | 22.4 | 19.2 | 22.1 |
| **Retention** | | | |
| Intake – excretion (g/d) | 1.73 ± 0.98[a] | 3.70 ± 1.31[b] | 3.05 ± 1.32[b] |
| % of N consumed | 11.2 | 25.6 | 27.4 |

Superscripts that differ on the same line denote values that are statistically different at the $P<0.05$ level.

## 4.9 ATROPINE AND THE GASTRO INTESTINAL TRACT

Atropine was injected subcutaneously as atropine sulphate at a rate of 0.4mg/kgW. The drug was administered to the subgroups of 4 goats each on day 8 (day of water deprivation). The other half of each group received atropine subcutaneously at a rate of 0.4mg/kgW on the 11$^{th}$

day of the trial which coincided with water deprivation for the treatment groups similarly like that of the first subgroups.

The results from the atropine analysis on blood plasma were not rewarding, as there were neither the trace of the drug nor any of its metabolites in the plasma. The above results from the water deprivation period also indicate no differences that could be attributed to the atropine administration.

## 4.10 HYDRATION STATUS

Results of the hydration status of the experimental goats as monitored during both trials are shown in Appendix 7. The physiological parameters used to deduce the hydration status of the animals are haematocrit, total plasma protein (TPP) and plasma osmolarity.

### 4.10.1 HAEMATOCRIT (PCV)

During the 1st trial, the average haematocrit for the groups were 34.6%, 29.4% and 32.4% for the control, 50% and 30% groups respectively.

The results showed that water restriction did not have any effect on PCV values in these experimental goats, as the normal PCV values range from 22to 38% (Duncan and Prasse, 1986).

The average haematocrit values for water deprived goats (trial 2) as calculated from Appendix 7 are 27.2%, 30.5% and 31.6% for the control group, 3-day and 5-day water deprivation groups respectively.

These values are also within the normal range (22 – 38%) for domestic goats (Duncan and Prasse, 1986), hence there was no effect on the PCV values of these animals despite the treatment.

## 4.10.2 TOTAL PLASMA PROTEIN (TPP)

The average TPP for the groups during water restriction are as follows 6.4g/dl, 6.7g/dl and 6.9g/dl for the control, 50% and 30% groups respectively.

The results aligned with normal TPP values of 6.0 to 7.5g/dl (Duncan and Prasse, 1986), hence no effect on the TPP values can be attributed to water restriction in these goats.

The average TPP values during water deprivation are 6.3g/dl, 6.5g/dl and 7.5 g/dl for the control group, 3-day and 5-day water deprivation groups respectively.

The results showed that the average TPP values of the 3 groups differ in this trial, however the values did not deviate from normal (Duncan and Prasse, 1986).

## 4.10.2 PLASMA OSMOLARITY

When the raw data in Appendix 7 were calculated, the average plasma osmolarity obtained for water restricted goats ( trial 1) are 316.4 mosm/kg, 327.7 mosm/kg, and 328.7 mosm/kg for the control, 50% and 30% groups respectively.

The values of plasma osmolarity obtained during water deprivation are 219.3 mosm/kg, 220.2 mosm/kg and 313.3 mosm/kg for the control group, 3-day and 5-day water deprivation groups respectively.

Values above 300 msom/kg (>300 mosm/kg) indicates hypertonicity (dehydration). Below 260 mosm/kg ( <260 mosm/kg ) indicates hypotonicity (overhydration) (Blood and Radostits, 1989).

# CHAPTER FIVE

# DISCUSSION AND CONCLUSION

## 5.1 FEED CONSUMPTION

All the animals consumed the diet very well during the adaptation period, even though they were newly introduced to the diet of lucerne /eragrostis hay (*Medicago sativa / Eragrostis curvula*) blended with molasses. The new environment (metabolic cages) did not affect their feed consumption. According to Qinisa and Boomker (1998), animals use experience to select and eat tasty food. This implies that most of the goats were acting on previous experience to eat the food as they had been exposed to experimental conditions in the past.

Shakespeare (1997) observed similar patterns of water consumption and urination in both treatment and control groups of sheep. He concluded that sheep do follow sheep alike, hence there was no difference in the observations made on both groups of experimental sheep in that study. One can deduce that the few young goats that thrived well on the diet in the present study might have copied the others, despite the fact that they were in - experienced and unaccustomed to experimental conditions.

The rate of feed consumption by the treatment groups in both trials was reduced due to regulated water intake. Previous studies show that feed intake and water intake are linearly related such that reducing water intake leads to a corresponding reduction in feed intake [Balch et al (1953); MacFarlane and Howard (1972); Silanikove (1985); Silanikove (1987)]. In the present study, the reduced appetite of the goats on 30%

*ad libitum* water intake and 5 -day water deprivation was significantly different (P< 0.05) compared to the appetite of the respective control group. Therefore one can recommend the provision of 50% *ad libitum* water or 3 -day water deprivation as the maximum water restriction allowed without reduction in dry matter intake (DMI) by goats on maintenance ration.

## 5.2 NUTRIENT UTILISATION

The imposed stress of low water intake and a correspondingly reduced appetite enhanced the digestibility of nutrients by ruminant animals. According to Silanikove (1992), water restriction and water deprivation reduced appetite and enhanced nutrient utilisation. The goats used in this study did not digest the dry matter more effectively when they were deprived or restricted of water. The DM digestibility coefficient of the control group tends to be slightly higher than the values obtained for the water restricted groups and significantly (P<0.05) higher when the goats were on the water deprivation treatment. These results were in conflict with previous observations made on goats given water once in 2 to 4 days [Gihad (1976); More and Sahni (1981)].

The conclusion of Brown (1966), from an extensive review of literature, that reducing the feed intake of ruminants resulted in significantly higher digestibility co-efficients for all nutrients also conflicted with the results of the present study. Thornton and Yates (1968) concurred with this concept as they reported an increase in digestion due to reduction in feed and water consumption by cattle. The changes in the digestion of nutrients by goats during the present water restriction trial were not consistent within and between groups (Appendix 2 and Table 3). There was no significant difference in digestibility co-efficient of most nutrients

by the goats under water deprivation. Table 4 also show that there was disparity in fluctuations of the overall nutrient digestibilities by the goats.

The inconsistent fluctuations observed in nutrient digestiblities by the goats in these trials made any extrapolation from this study inconclusive. Thus, complimentary investigations are essential in order to establish the optimum requirement of water vis-à-vis optimum nutrient utilisation for maintenance in goats.

## 5.3 WATER MANAGEMENT

The total amount of water consumed by the goats on an *ad libitum* water regimen was more than that of the water-restricted and water-deprived animals in both trials. As shown in Tables 7 and 9, the average daily consumption was 1.49 litres for the control (*ad libitum)* group compared to 0.70 litres and 0.37 litres for 50% and 30% treatment groups respectively. The control group consumed an average of 1.54 litres daily during the second trial compared to 0.90 litres and 0.60 litres by water deprived goats, given water every 3$^{rd}$ and 5$^{th}$ day respectively. It has been previously demonstrated that goats drink small volumes of water [Devendra (1980); More and Sahni (1981)]. Qinisa and Boomker (1998) also confirmed this by summarising water consumption of some breeds of sheep and comparing these data with those obtained in indigenous goats.

French (1956) observed that water-deprived cattle fed with dry herbage and exposed to stressful long walks in search of water, patiently took their turn to drink, taking few gulps of water over a period of several minutes. Although this study did not investigate behaviour, it seemed to differ from that of goats, known to be unruly at the sight of water. However, the results of the present trials were consistent with the

second observation of French (1956). These goats did not consume water to their full capacity (relative to the control group) when given the opportunity to drink after either 3 or 5 days of water deprivation.

It was of interest to note that the goats used in these trials differ significantly ($P<0.05$) on the use of water to meet their needs such as perspiration and evaporation. The average calculated insensible water loss for the groups was 57.8%, 35.7%, 10.8% of total intake for the groups that were restricted (control, 50% and 30% respectively) and 43.5%, 36.7%, 23.3% for the groups that were deprived of water (control, 3-day and 5-day water regimen respectively) (Tables 7 and 9). One would have expected the same species of animals, housed and fed under the same environmental conditions, to show similar values of insensible loss, since they have the same physiological demands. Further studies should be conducted to elucidate this wide disparity of water use in this species.

When the goats were on water restriction trial, the water lost through the faeces and urine by the treatment groups was higher (89.2% and 64.3% by 30% and 50% groups respectively) compared to the amount lost by the goats on *ad libitum* water (control: 42.3%). Similarly, the water excreted through these routes (faeces and urine) by the control group was lower (56.5%) than that lost by their counter-parts (63.4% and 76.6%) during the 3-day and 5-day water deprivation trial. This was contrary to previous observations that restricting the water intake of ruminants will lead to the conservation of water through excretory routes [English (1966); More and Sahni (1981)].

Goats are known to have a lower water requirement than most ruminant species. [ARC (1965); Gihad (1976); Gihad et al (1980)]. This was corroborated by Qinisa and Boomker (1998). When goats were subjected to different water regimens to compare water consumption relative to kilogram feed intake, it was found that they consumed a

relatively small volume of water, both during restriction and when given unlimited water to drink after deprivation (see Tables 1,2, 8 and 10).

The efficiency of water consumption by the goats may best be calculated as ml/kg$^{0.75}$/day. The values are 112.0, 55.5, 28.1 for the groups restricted to 100%, 50% and 30% respectively and 118.5, 68.7, 44.6 for the groups given water daily, every 3$^{rd}$ and 5$^{th}$ day respectively when on deprivation regimen (Tables 8 and 10). Those with low levels of water intake (restriction and deprivation) were found to be significantly ($P<0.05$) better utilisers of water than the control groups. In order of efficiency, 50% and 30% groups were higher than the control group while the 30% group also show significant better water efficiency than the 50% group when on water restriction regimen. Similarly goats deprived of water for 5 days have a higher water efficiency than those deprived for 3 days. Both groups also proved superior with regard to water management than the control group.

## 5.4 CHANGES IN BODY WEIGHT

Most of the experimental animals showed an increase in body weight during the first trial of water restriction. This was consistent with previous studies in which goats were fattened on a dry diet with a restricted water supply [Asdell (1950); Blaxter et al (1950)].

There was general loss in body weight by the goats subjected to water deprivation while few of them maintained their body weight during the trial (Appendix 5). This loss in body weight was subsequently regained on rehydration within a few days. A similar observation was made on water-deprived Bedouin goats whose loss in body weight was fully compensated for during one short drinking bout [Brosh et al (1987); Choshniak and Shkolnik (1978)]. One can deduce from these observations that moderate water restriction and deprivation appear to lead primarily to loss of body water and not tissue mass, and therefore do not have adverse effects on production in ruminant animals.

## 5.5 NITROGEN BALANCE

The reduced voluntary feed intake which accompanied the water restriction led to a decreased nitrogen consumption by the treatment groups 10.79 g/d (50%) and 9.00 g/d (30%) compared to 12.75 g/d by the control group. This is a reflection of the higher feed consumption, as the main source of nitrogen to the goats is via the feed.

Correspondingly, the total nitrogen excretion decreased with the reduction in water intake. The total amounts of nitrogen excreted by the groups are as follows: control group (13.06 g/d); 50% group (8.71g/d) and 30% group (6.13 g/d). When these figures were expressed as a percentage of N-intake, it was found that the larger percentage was excreted via the faeces, thus control group (61.4%); 50% group (64.6%) and 30% group ( 48.9% ) as shown in Table 11.

The low N excretion by water-restricted goats facilitated increased N retention. The control group showed a negative nitrogen balance( -0.30 g/d) while treatment groups were able to retain high amount of nitrogen. The percentage of nitrogen retained by these groups expressed, as a function of nitrogen intake was significantly higher ($P< 0.05$) than that of the control group. These observations aligned with earlier reports that restricting water intake of ruminants results in decreased nitrogen excretion and improved nitrogen retention (English (1966); Topps and Elliot (1967)]. According to Kimambo et al (1999), this might be associated with low ammonia production in the rumen, due to low rate of degradation, thereby allowing most of the protein to escape ruminal digestion. This may be digested in the abomasum and small intestine. The elevated nitrogen uptake from the small intestine may lead to increased metabolism in the liver and could result in enhanced nitrogen recycling into the rumen.

The nitrogen utilisation data presented in Table 12 also show that water deprivation is associated with decreased nitrogen intake, a function of low feed intake by water deprived animals. Thus N intake reduced from 15.42 g/d to 14.45 g/d to 11.13 g/d for the control group, 3-day and 5-day deprivation groups respectively.

Similarly, reduced N intake led to a correspondingly low nitrogen loss via the faeces and urine by the treatment groups. The control group excreted 13.68 g/d while 3-day and 5-day groups lost 10.75 g/d and 8.08 g/d of N respectively. It was also observed that a larger percentage of N intake was excreted via the faeces by the three groups thus: 66.3% (control); 55.2% (3-day) and 50.5% (5-day). This was a reflection of feed consumption and faecal output, thus a high feed intake produced a high faecal loss of nitrogen.

In the same vein, the water deprived goats (treatment groups) had improved nitrogen retention and the amount retained was significantly higher ($P<0.05$) than that of goats on *ad libitum* daily water regimen (control group). Similar observations were made in sheep deprived of water for 48 hours [Singh et al (1976)].

Topps and Elliot (1967) reported that limited water intake by ruminants probably leads to a smaller amount of urea loss via the kidneys, which in turn increases the amount of urea recycled to the rumen. The significantly low quantity of urea (Table 5) lost by the goats during water restriction (82.9 and 82.6 mmol/d compared to 249.0 mmol/d by the control group), and deprivation (136.9 and 117.0 mmol/d compared to 164.6 mmol/d by the control group) in the present study might facilitate their ability to recycle urea.

The urea recycled to the rumen coupled with the favourable nitrogen balance of these goats (water restricted and deprived groups) would

elevate ammonia production by ruminal microbes. According to Kimambo et al (1999), the improved conditions in the rumen enhance the digestion of nutrients consumed by these ruminant animals.

## 5.6 EFFECTS OF ATROPINE

Atropine is known to produce dose-related effects at various muscarinic receptor sites [Duncan (1954); Eger (1962)]. Duncan (1954) observed inhibition of the gastric motility in sheep injected with 10 – 20 mg atropine sulphate. There was a reduction in tone and motility of the gastro-intestinal tract (GIT) when 0.1 – 1 mg/kg BW atropine was administered to vagotomized sheep [Gregory (1954); Ruckebusch et al (1972)]. Similar observations were made in intact sheep by Cottrell and Iggo (1984). These studies show that atropine has a definite effect on the GIT when administered in large doses.

Gordon et al (1985) used transdermal scopolamine to produce a reduction in salivary flow in human subjects. Although atropine is less potent than scopolamine, as an antisialogogue agent, the fact remains that anticholinergic drugs can inhibit salivary secretion when administered in large doses [Eger (1962); Gordon et al (1985)].

In the present study, the dose of atropine administered to the animals was below the pharmacological level required to produce the desired effects on the gastro-intestinal and uro-genital tracts. Although the results of the water deprivation trials were thoroughly analysed, no change in the parameters measured could be ascribed to the effect of the atropine administration alone. Further studies should be carried out with atropine at higher doses to elucidate more on the effects of the drug on gastro-intestinal functions of ruminant animals.

## 5.7 CONCLUSION

The goats used in this study demonstrated high water efficiency. The limited supply of water decreased feed intake but enhanced nutrient utilisation particularly by 50% group and those watered once in 3 days. In view of these concepts, one can propose a strategy of providing water 50% *ad libitum* or once in 3 days for goat production in adverse conditions. This is not only economical but also even beneficial, and as stated by French (1956), it allows exploitation of grazing areas far from water and prevents erosion in the vicinity of water. This is relevant in areas of tropical Africa where water is scarce and grazing pressure is high.

Atropine was administered on the goats at a low pharmacological dose necessary to influence gastro-intestinal functions. The plasma analysis for the drug was unrewarding, hence complimentary investigations should be done using atropine at higher doses. This is with a view to elucidate more on the effects of the drug on gastrointestinal functions of ruminant animals.

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# APPENDICES

a. Control group on 100% *ad libitum* water intake during water restriction
b. Goats given 50% *ad libitum* water intake
c. Goats given 30% *ad libitum* water intake
d. Control group on *ad libitum* daily water regimen during water deprivation and atropine administration trial
e. Goats given water once in 3 days
f. Goats given water once in 5 days

# Appendix 1 – Average Water Intake and Feed Intake

a)

| G No | Water intake (L) | Feed intake (kg) |
|---|---|---|
| 1 | 2.11 | 1.07 |
| 2 | 1.28 | 0.81 |
| 3 | 1.16 | 0.65 |
| 4 | 1.08 | 0.67 |
| 5 | 1.50 | 0.61 |

b)

| | | |
|---|---|---|
| 6 | 0.61 | 0.64 |
| 7 | 0.54 | 0.74 |
| 8 | 0.74 | 0.66 |
| 9 | 0.60 | 0.48 |
| 10 | 0.78 | 0.70 |

c)

| | | |
|---|---|---|
| 11 | 0.35 | 0.64 |
| 12 | 0.32 | 0.64 |
| 13 | 0.33 | 0.52 |
| 14 | 0.34 | 0.43 |
| 15 | 0.29 | 0.46 |

# Appendix 1 - Average Water Intake and Feed Intake

d)

| G No | Water intake (L) | Feed intake (kg) |
|---|---|---|
| 6 | 2.18 | 1.03 |
| 9 | 1.31 | 0.74 |
| 10 | 1.85 | 1.04 |
| 11 | 1.40 | 1.07 |
| 12 | 1.21 | 0.99 |
| 13 | 1.43 | 0.89 |
| 14 | 1.05 | 0.74 |
| 15 | 1.32 | 0.94 |

e)

| | | |
|---|---|---|
| 1 | 3.13 | 1.08 |
| 2 | 2.77 | 0.88 |
| 3 | 2.07 | 0.76 |
| 4 | 2.10 | 0.67 |
| 5 | 1.47 | 0.65 |
| 7 | 2.97 | 0.93 |
| 8 | 3.23 | 0.78 |
| 16 | 2.50 | 0.63 |

f)

| | | |
|---|---|---|
| 6 | 2.95 | 0.90 |
| 9 | 1.25 | 0.47 |
| 10 | 3.63 | 0.95 |
| 11 | 2.83 | 0.76 |
| 12 | 3.20 | 0.88 |
| 13 | 2.75 | 0.76 |
| 14 | 2.28 | 0.65 |
| 15 | 2.75 | 0.85 |

Appendix 2 – Average Daily Nutrients Intake and Digestibility

a)

| G No | DRY MATTER | | CRUDE PROTEIN | | A D F | |
|---|---|---|---|---|---|---|
| | Intake (g/d) | Dig (%) | Intake(g/d) | Dig (%) | Intake (g/d) | Dig(%) |
| 1 | 985.16 | 59.3 | 112.02 | 38.1 | 419.40 | 48.9 |
| 2 | 744.37 | 60.0 | 84.64 | 38.7 | 316.89 | 52.8 |
| 3 | 597.69 | 58.8 | 67.96 | 43.2 | 254.45 | 57.1 |
| 4 | 613.34 | 57.0 | 69.74 | 45.3 | 261.11 | 53.9 |
| 5 | 564.54 | 54.9 | 64.19 | 27.4 | 240.34 | 42.0 |

b)

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | 593.17 | 62.2 | 67.45 | 28.1 | 252.52 | 42.3 |
| 7 | 684.90 | 60.0 | 77.88 | 51.5 | 291.57 | 66.9 |
| 8 | 607.77 | 55.0 | 69.11 | 25.3 | 258.74 | 41.0 |
| 9 | 437.47 | 58.8 | 49.74 | 42.7 | 186.24 | 53.7 |
| 10 | 641.26 | 54.7 | 72.92 | 29.4 | 273.00 | 44.6 |

c)

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | 587.05 | 56.6 | 66.8 | 44.4 | 249.92 | 58.9 |
| 12 | 590.65 | 62.7 | 67.2 | 53.2 | 251.45 | 63.6 |
| 13 | 476.23 | 54.2 | 54.2 | 46.5 | 202.74 | 61.3 |
| 14 | 395.00 | 44.9 | 44.9 | 54.5 | 168.16 | 53.7 |
| 15 | 425.63 | 48.4 | 48.4 | 40.0 | 181.20 | 68.8 |

Appendix 2 – Average Daily Nutrients Intake and Digestibility

d)

| G No | DRY MATTER | | CRUDE PROTEIN | | ADF | |
|---|---|---|---|---|---|---|
| | Intake (g/d) | Dig (%) | Intake (g/d) | Dig (%) | Intake (g/d) | Dig(%) |
| 6 | 975.63 | 56.8 | 110.93 | 29.4 | 415.34 | 35.0 |
| 9 | 674.12 | 57.3 | 76.65 | 34.7 | 286.98 | 40.8 |
| 10 | 986.45 | 67.2 | 112.17 | 33.8 | 419.95 | 46.2 |
| 11 | 933.55 | 66.7 | 106.15 | 66.5 | 397.43 | 55.1 |
| 12 | 888.85 | 57.0 | 101.07 | 33.8 | 378.40 | 46.1 |
| 13 | 841.61 | 63.8 | 95.70 | 33.8 | 358.28 | 49.6 |
| 14 | 644.70 | 67.1 | 73.31 | 32.0 | 274.46 | 42.8 |
| 15 | 836.64 | 62.2 | 95.13 | 39.0 | 356.17 | 51.3 |

e)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 1080.01 | 41.2 | 122.80 | 46.6 | 459.78 | 55.2 |
| 2 | 893.04 | 62.0 | 101.54 | 42.8 | 380.18 | 54.6 |
| 3 | 694.19 | 57.7 | 78.93 | 44.1 | 295.53 | 52.7 |
| 4 | 665.60 | 62.5 | 75.68 | 50.4 | 283.36 | 58.9 |
| 5 | 570.21 | 59.4 | 64.84 | 41.5 | 242.75 | 50.8 |
| 7 | 985.03 | 71.8 | 112.00 | 52.9 | 419.34 | 64.1 |
| 8 | 760.81 | 60.7 | 86.51 | 40.6 | 323.89 | 37.1 |
| 16 | 706.25 | 61.1 | 80.30 | 36.4 | 300.66 | 35.4 |

f)

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | 631.99 | 47.1 | 71.86 | 44.8 | 269.05 | 38.9 |
| 9 | 183.06 | 43.8 | 20.81 | 46.2 | 77.93 | 39.7 |
| 10 | 746.45 | 58.2 | 84.88 | 49.2 | 317.77 | 44.4 |
| 11 | 700.27 | 62.1 | 79.62 | 51.0 | 298.12 | 58.8 |
| 12 | 751.42 | 59.9 | 85.44 | 51.4 | 319.89 | 54.7 |
| 13 | 605.15 | 56.1 | 68.81 | 48.1 | 257.62 | 48.4 |
| 14 | 584.62 | 52.2 | 66.47 | 45.4 | 248.88 | 40.1 |
| 15 | 688.67 | 62.9 | 78.31 | 56.4 | 293.18 | 60.5 |

## Appendix 3 – Average Urine Output and Urea Output

a)

| G No | Urine | Urea | |
|---|---|---|---|
| | Vol (l/d) | conc mmol/L | Vol (mmol/d) |
| 1 | 0.98 | 972.83 | 953.37 |
| 2 | 0.31 | 298.17 | 92.43 |
| 3 | 0.05 | 544.11 | 27.21 |
| 4 | 0.18 | 536.17 | 96.51 |
| 5 | 0.28 | 270.14 | 75.64 |

b)

| | | | |
|---|---|---|---|
| 6 | 0.25 | 445.89 | 111.47 |
| 7 | 0.32 | 325.09 | 104.03 |
| 8 | 0.23 | 468.67 | 107.79 |
| 9 | 0.10 | 456.12 | 45.61 |
| 10 | 0.14 | 324.41 | 45.42 |

c)

| | | | |
|---|---|---|---|
| 11 | 0.25 | 347.29 | 86.82 |
| 12 | 0.22 | 416.90 | 91.72 |
| 13 | 0.16 | 351.78 | 56.28 |
| 14 | 0.13 | 306.73 | 39.87 |
| 15 | 0.34 | 406.81 | 138.32 |

Appendix 3 Average Urine Output and Urea Output

d)

| G No | Urine | Urea | |
|---|---|---|---|
| | Vol (l/d) | conc (mmol/L) | (mmol/d) |
| 6 | 0.32 | 756.58 | 242.11 |
| 9 | 0.39 | 296.05 | 115.46 |
| 10 | 0.54 | 473.69 | 255.79 |
| 11 | 0.56 | 309.21 | 173.16 |
| 12 | 0.57 | 302.63 | 172.50 |
| 13 | 0.25 | 414.48 | 103.62 |
| 14 | 0.36 | 302.64 | 108.95 |
| 15 | 0.34 | 427.63 | 145.39 |

e)

| | | | |
|---|---|---|---|
| 1 | 0.34 | 440.80 | 149.87 |
| 2 | 0.42 | 513.16 | 215.53 |
| 3 | 0.23 | 710.53 | 163.42 |
| 4 | 0.14 | 986.85 | 138.16 |
| 5 | 0.12 | 385.97 | 46.32 |
| 7 | 0.29 | 710.53 | 206.05 |
| 8 | 0.21 | 508.77 | 106.84 |
| 16 | 0.15 | 460.53 | 69.08 |

f)

| | | | |
|---|---|---|---|
| 6 | 0.25 | 493.59 | 123.40 |
| 9 | 0.09 | 589.74 | 53.08 |
| 10 | 0.18 | 525.64 | 94.62 |
| 11 | 0.29 | 583.34 | 169.17 |
| 12 | 0.32 | 365.39 | 116.92 |
| 13 | 0.29 | 397.44 | 115.26 |
| 14 | 0.19 | 451.42 | 85.77 |
| 15 | 0.22 | 807.70 | 177.69 |

# Appendix 4 – Average Daily Faeces Output and Faecal Water Loss

a)

| G No | Faeces (g) | Moisture (%) | Water loss (L) |
|---|---|---|---|
| 1 | 803.0 | 50.0 | 0.40 |
| 2 | 578.1 | 48.5 | 0.28 |
| 3 | 426.4 | 42.3 | 0.18 |
| 4 | 439.4 | 40.0 | 0.18 |
| 5 | 546.7 | 53.4 | 0.29 |

b)

| | | | |
|---|---|---|---|
| 6 | 569.6 | 60.6 | 0.35 |
| 7 | 427.7 | 35.9 | 0.15 |
| 8 | 561.7 | 51.3 | 0.29 |
| 9 | 311.6 | 42.1 | 0.13 |
| 10 | 555.8 | 47.8 | 0.27 |

c)

| | | | |
|---|---|---|---|
| 11 | 401.5 | 36.6 | 0.15 |
| 12 | 351.8 | 37.3 | 0.13 |
| 13 | 294.0 | 32.9 | 0.10 |
| 14 | 289.7 | 36.1 | 0.10 |
| 15 | 212.3 | 29.6 | 0.06 |

## Appendix 4 – Average Daily Faeces Output and Faecal Water Loss

d)

| G No | Faeces (g) | Moisture (%) | Water loss (L) |
|---|---|---|---|
| 6 | 1074.9 | 60.8 | 0.65 |
| 9 | 676.8 | 57.5 | 0.39 |
| 10 | 875.7 | 63.0 | 0.55 |
| 11 | 711.2 | 56.3 | 0.40 |
| 12 | 812.7 | 53.0 | 0.43 |
| 13 | 749.6 | 59.3 | 0.44 |
| 14 | 573.0 | 63.0 | 0.36 |
| 15 | 672.6 | 53.0 | 0.36 |

e)

| | | | |
|---|---|---|---|
| 1 | 808.2 | 45.0 | 0.36 |
| 2 | 707.3 | 52.0 | 0.37 |
| 3 | 541.7 | 45.8 | 0.25 |
| 4 | 456.8 | 45.3 | 0.21 |
| 5 | 470.5 | 50.8 | 0.24 |
| 7 | 595.5 | 53.3 | 0.32 |
| 8 | 757.2 | 60.5 | 0.46 |
| 16 | 733.0 | 62.5 | 0.46 |

f)

| | | | |
|---|---|---|---|
| 6 | 637.1 | 47.5 | 0.30 |
| 9 | 181.6 | 43.3 | 0.08 |
| 10 | 647.1 | 51.8 | 0.34 |
| 11 | 470.4 | 43.5 | 0.20 |
| 12 | 536.4 | 43.8 | 0.23 |
| 13 | 483.3 | 45.0 | 0.22 |
| 14 | 540.5 | 48.3 | 0.26 |
| 15 | 421.5 | 39.3 | 0.17 |

# Appendix 5 - Body Weight Variation of Goats

a)

| G No | Before trial (kg) | After trial (kg) |
|---|---|---|
| 1 | 41.6 | 41.5 |
| 2 | 34.8 | 34.5 |
| 3 | 31.5 | 31.5 |
| 4 | 25.7 | 25.5 |
| 5 | 20.4 | 20.0 |
| | | |

b)

| | | |
|---|---|---|
| 6 | 36.2 | 36.0 |
| 7 | 33.8 | 36.0 |
| 8 | 24.8 | 23.0 |
| 9 | 17.5 | 17.5 |
| 10 | 29.6 | 31.5 |

c)

| | | |
|---|---|---|
| 11 | 43.5 | 45.0 |
| 12 | 29.6 | 31.5 |
| 13 | 24.4 | 26.5 |
| 14 | 16.2 | 14.5 |
| 15 | 30.6 | 31.0 |

## Appendix 5 - Body Weight Variation of Goats

d)

| G No | Before trial (kg) | After trial (kg) |
|---|---|---|
| 6 | 36.0 | 36.5 |
| 9 | 17.5 | 18.5 |
| 10 | 31.5 | 31.5 |
| 11 | 45.0 | 44.0 |
| 12 | 31.5 | 32.0 |
| 13 | 26.5 | 26.5 |
| 14 | 14.5 | 17.5 |
| 15 | 31.0 | 32.0 |

e)

| | | |
|---|---|---|
| 1 | 41.5 | 40.5 |
| 2 | 34.5 | 32.5 |
| 3 | 31.5 | 30.0 |
| 4 | 25.5 | 25.0 |
| 5 | 20.0 | 20.0 |
| 7 | 36.0 | 33.5 |
| 8 | 23.0 | 22.5 |
| 16 | 26.5 | 25.6 |

f)

| | | |
|---|---|---|
| 6 | 36.5 | 36.5 |
| 9 | 18.5 | 17.0 |
| 10 | 31.5 | 30.0 |
| 11 | 44.0 | 44.0 |
| 12 | 32.0 | 30.0 |
| 13 | 26.5 | 25.0 |
| 14 | 17.5 | 16.0 |
| 15 | 32.0 | 31.5 |

Appendix 6 - Average Daily Nitrogen Balance

a)

| G No | N Intake(g) | Faecal N (g) | Urinary N (g) | N Retained (g) |
|---|---|---|---|---|
| 1 | 17.92 | 11.09 | 20.02 | -13.19 |
| 2 | 13.54 | 8.30 | 1.94 | 3.30 |
| 3 | 10.87 | 6.17 | 0.57 | 4.13 |
| 4 | 11.16 | 6.11 | 2.03 | 3.02 |
| 5 | 10.27 | 7.64 | 1.59 | 1.22 |

b)

| | | | | |
|---|---|---|---|---|
| 6 | 10.79 | 7.76 | 2.34 | 0.69 |
| 7 | 12.46 | 6.05 | 2.18 | 4.23 |
| 8 | 11.06 | 8.26 | 2.26 | 0.54 |
| 9 | 7.96 | 4.56 | 0.96 | 2.44 |
| 10 | 11.67 | 8.24 | 0.95 | 2.48 |

c)

| | | | | |
|---|---|---|---|---|
| 11 | 10.68 | 5.94 | 1.82 | 2.92 |
| 12 | 10.75 | 5.03 | 1.93 | 3.79 |
| 13 | 8.66 | 4.03 | 1.18 | 3.45 |
| 14 | 7.19 | 3.92 | 0.84 | 2.43 |
| 15 | 7.74 | 3.10 | 2.87 | 1.77 |

## Appendix 6 – Average Daily Nitrogen Balance

d)

| G No | N Intake(g) | Faecal N (g) | Urinary N (g) | N Retained (g) |
|---|---|---|---|---|
| 6 | 17.75 | 12.54 | 5.09 | 0.12 |
| 9 | 12.26 | 8.01 | 2.43 | 1.82 |
| 10 | 17.95 | 11.88 | 5.37 | 0.70 |
| 11 | 16.98 | 11.30 | 3.64 | 2.04 |
| 12 | 16.17 | 10.70 | 3.63 | 1.84 |
| 13 | 15.31 | 10.13 | 2.18 | 3.00 |
| 14 | 11.73 | 7.98 | 2.29 | 1.46 |
| 15 | 15.22 | 9.29 | 3.06 | 2.87 |

e)

| | | | | |
|---|---|---|---|---|
| 1 | 19.65 | 10.50 | 3.15 | 6.00 |
| 2 | 16.25 | 9.30 | 4.53 | 2.42 |
| 3 | 12.63 | 7.05 | 3.43 | 2.15 |
| 4 | 12.11 | 6.01 | 2.90 | 3.20 |
| 5 | 10.37 | 6.08 | 0.73 | 3.56 |
| 7 | 17.92 | 8.44 | 4.33 | 5.15 |
| 8 | 13.84 | 8.23 | 1.69 | 3.92 |
| 16 | 12.85 | 8.17 | 1.45 | 3.23 |

f)

| | | | | |
|---|---|---|---|---|
| 6 | 11.50 | 6.35 | 2.59 | 2.56 |
| 9 | 3.33 | 1.79 | 1.11 | 0.43 |
| 10 | 13.58 | 6.89 | 1.99 | 4.70 |
| 11 | 12.74 | 6.25 | 3.55 | 2.94 |
| 12 | 13.67 | 6.65 | 2.46 | 4.56 |
| 13 | 11.01 | 5.72 | 2.42 | 2.87 |
| 14 | 10.64 | 5.81 | 1.80 | 3.03 |
| 15 | 12.53 | 5.47 | 3.73 | 3.33 |

# Appendix 7 - Average PCV, TPP and Plasma osmolarity

a)

| G No | PCV (%) | TPP (g/dL) | Osmolarity (mosm/kg) |
|---|---|---|---|
| 1 | 31 | 6.3 | 308.5 |
| 2 | 37 | 5.9 | 322 |
| 3 | 36 | 6.6 | 323 |
| 4 | 36 | 6.4 | 314 |
| 5 | 33 | 6.8 | 314.5 |

b)

| | | | |
|---|---|---|---|
| 6 | 35 | 6.8 | 325.5 |
| 7 | 24 | 6.5 | 332 |
| 8 | 23 | 6.9 | 330 |
| 9 | 30 | 6.9 | 325.5 |
| 10 | 35 | 6.3 | 325.5 |

c)

| | | | |
|---|---|---|---|
| 11 | 36 | 6.9 | 323.5 |
| 12 | 32 | 6.6 | 326 |
| 13 | 33 | 7.1 | 329.5 |
| 14 | 26 | 7.0 | 338.5 |
| 15 | 35 | 6.8 | 327 |

Appendix 7 – Average PCV, TPP and Plasma osmolarity

d)

| G No | PCV (%) | TPP (g/dl) | Osmolarity (mosm/kg) |
|---|---|---|---|
| 6 | 27.5 | 6.9 | 221.5 |
| 9 | 27.5 | 6.3 | 218.5 |
| 10 | 25.5 | 6.0 | 219 |
| 11 | 30.5 | 6.3 | 222 |
| 12 | 26 | 5.7 | 216.5 |
| 13 | 29 | 6.5 | 221.5 |
| 14 | 23 | 6.2 | 216 |
| 15 | 28.5 | 6.4 | 219 |

e)

| | | | |
|---|---|---|---|
| 1 | 29 | 6.6 | 230 |
| 2 | 34 | 5.9 | 219 |
| 3 | 32 | 6.2 | 221.5 |
| 4 | 35.5 | 6.2 | 224 |
| 5 | 33 | 6.8 | 227 |
| 7 | 25 | 6.5 | 216 |
| 8 | 22.5 | 6.4 | 216.5 |
| 16 | 33 | 7.1 | 217.5 |

f)

| | | | |
|---|---|---|---|
| 6 | 35.5 | 7.7 | 309.5 |
| 9 | 37.5 | 7.2 | 311 |
| 10 | 31.5 | 6.3 | 307.5 |
| 11 | 30.5 | 6.4 | 309.5 |
| 12 | 28 | 6.3 | 330 |
| 13 | 33 | 6.7 | 314.5 |
| 14 | 25 | 6.1 | 310 |
| 15 | 32 | 6.7 | 314.5 |