WATER METABOLISM OF INDIGENOUS NIGERIAN SHEEP AND GOATS

BY

ADEMIJU ADEOLU AGANGA
B.Sc. Agric. (with,Special Honours in Animal Science) University of Ibadan, 1977.

M.Sc. Animal Science, Ahmadu Bello University, Zaria.

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A

DISSERTATION

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DIGITIZED

A. A. Aganga

A. A. Aganga (Mrs.)
(Name & Signature of Candidate)

Date: November, 1987

CERTIFICATION

This thesis entitled Water metabolism of indigenous Nigerian sheep and goats by A.A. Aganga, meets the regulations governing the degree of Doctor of Philosophy of Ahmadu Bello University and is approved for its contribution to scientific knowledge and literary presentation.

Internal Examiners

Professor N. N. Umunna
(Chairman, Supervisory Committee)
Head, Dept. of Animal Science
Ahmadu Bello University, Zaria.

Dr. E. O. Oyedipe
Programme Leader,
Animal Reproduction
N.A.P.R.I., A.B.U., Zaria.

Dean, Postgraduate School

Professor D. I. Saror

DEDICATION

This thesis is dedicated to my children,
Tunbosun Jnr., 'Laolu, 'Layemi and 'Ladapo.

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ABSTRACT

Nine feeding experiments and one metabolism study were conducted to investigate the water requirements and metabolism of some indigenous Nigerian sheep and goats including the various factors that influence it in the Sudan Savanna Zone. The studies conducted examined the wrter balance, seasonal variations, breed effect, diet effect, influence of feed and water deprivation end also effect of physiologic states on water requirements of these indigenous Nigerian sheep and goats.

Growth performance of the indigenous penned sheep breeds were much better than that of the goats for example average daily gain (ADG) for Yankasa was 0.110kg while that of Mcradi was 0.P5kg. Composition of the whole bodies of sheep and goats showed that water component ranged from 52.37 - 71.51% for sheep and 48.16 - 74.69% for goats. Tritiated water space (TOH) as percentage of liveweight was (66.1%) for Maradi goats, 73.6% for Yankasa, 80.5% for Ouda and 77.8% for Sahel. The biological half-life of tritium was least in Yankasa (1T5.5h) and longest in Sahel (I73.3h). Water turnover per day/animal was 2.52L, 2,63L, 0.86L, 1.0L for Ouda sheep, Yankasa sheep, Sahel goat, and Mrradi goats breeds respectively.

The results showed a variation in water requirement with age of sheep and goats but no conclusion could be drawn for relationship between sex and water requirement.

Also results showed significant (P/O.01) effects of seasonal variations on water requirements of Yankasa sheep. Water deprivation depressed the growth performance of Yankasa sheep and this was very prominent in the hot dry season.

Water restriction negatively affected the growth, lactation and pregnancy performance of Yankasa ewes. Milk yield dropped drastrically when water was not given daily to lactating Yankasa ewes. Pregnant ewes watered 72hourly aborted or gave birth to weak lambs.

Feed restriction in sheep resulted in reduced water intake and consequent weight loss. Results of the metabolism study showed that Maradi goats produced drier faeces than Yankasa sheep. At high environmental temperatures, evaporative water loss plays an important role in regulating body temperature. Evaporative water loss of the Yankasa sheep was l62.4ml/kg0.73/day while it was 120.4ml/$kg^{0.73}$/day for Maradi goats. The percentage faecal water ranged between 50-60% for Yankasa and 40-45% for Maradi goats.

Investigations with sheep and goats showed a great influence of diet on water intake. Sheep and goats on low protein rations drank less water than those on high protein rations.

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INTRODUCTION

Water, the simplest of all substances in foods, is not the simplest to determine. Usually it is recorded as the loss in weight of a sample as a result of oven-drying to a constant weight at atmospheric pressure and at a temperature just above the boiling point of water. The significance of the water content of feeds depends on the kind of feed and the amount of water. The greatest difference in nutritive value between many feeds is traceable to differing moisture content.

Water is a dietary essential. Animals' first response to a restriction of water intake is a restriction of voluntary feed intake. The water content of feeds, particularly those that are normally high in water, such as silage, fluid milk, pasture forage and roots, is an important consideration in their feeding value and in the overall requirement of the animal for water. Water that is not supplied with food must be supplied from some other source, and some foods owe their chief nutritional properties to their water content.

Water intake by animals is controlled by the capacity of the digestive system. The water requirement for specific animals, depends on the composition of the animals' diets. Crampton and Harris (1969) reported that the approximate water that should be provided as beverage, where it is impossible to furnish water

ad libitum, may be calculated from the caloric requirement. The digestive calorie intake for any animal is not far from metabolic size. The quantity of water to be provided as beverage is, for average conditions, one milliliter per metabolic size. The balance of the day's water is provided by metabolic water and that which is contained as free water in the foods eaten.

The presence of adequate water in body tissues is an essential prerequisite for the normal maintenance of life, and water is a fundamental constituent of all living cells. It is so intimately concerned with the transformation of nutrient and excretory matter between the digestive system, the cells of the different body tissues and the excretory organs. French (1956) reported that starving animals may lose nearly all their glycogen and fatty reserves, half their body protein and about 40 percent of their bodyweight and still live while the loss of only 10 percent of body water causes serious disorders and further losses may quickly lead to death. The latter also reported that temporary water shortages are consequently of greater immediate significance than corresponding deficiencies of solid foods. In the semi-arid regions, where droughts alternate with seasonal and often short rainy periods, and where livestock experience serious

difficulties in finding and consuming sufficient herbage to maintain growth, reproduction and normal sustenance; the seasonal water shortages exert such dominating influences that attention is quickly and importantly needed on water requirements of livestock especially ruminants.

Apart from specific production needs, French (1956) reported that water is constantly needed to balance the continuous losses from the kidneys, the intestinal tract, the skin and the lungs. In urine, water is the vehicle for the excretion of a number of catabolic products particularly minerals and urea, and the richer the diet in minerals and proteins the larger are the quantities excreted and the greater the volume of water required for their solution and transport.

Robinson (1957) reported that water was uniquely suited to become the inorganic basis of living matter. Its unusually high dielectric constant helps to bring ions into solution in the lower part of the range of temperatures in which it is liquid, and dissolved ions play a large part in maintaining essential properties of cell membranes and the activity of enzymes. Within cells, water appears rather as a physical substratum than as a chemical participant in the essential reactions which maintain life. The body water is not, of course, fresh water, but contains salts in solution; and the salts

inside and outside the cells are characteristically different. The chief cation of the extracellular fluid is sodium, there are also small but important concentrations of potassium and calcium, and chloride and bicarbonate make up the bulk of the accompanying anions. Robinson (1957) also reported that the chief cations in the cell is potassium and the accompanying anions are probably mostly organic phosphates.

In Nigeria, especially in the guinea and sahel savanna zone where there is a long period of dry season (as long as 8 months) in a year, water is not available all year-round. Consequently, the animals have to adapt to little or no water at certain times of the year. It is necessary therefore to know the actual amount of water required, by these animals. The specific objectives of this study were to investigate the following:-

1. Water balance of sheep and goats.
2. Breed differences in water metabolism of penned indigenous sheep and goats.
3. Effect of age and sex on water requirement of penned animals
4. Seasonal variations and influence of intermittent watering on grazing animals

5. Influence of diet type on water intake of sheep and goats.
6. Response of ewes under various physiologic states to water deprivation.
7. Effect of graded level and total feed deprivation on water requirement of sheep.
8. Influence of feed management on water intake of sheep.

These objectives have been conducted as experiment 1-8 respectively.

CHAPTER I

REVIE' OF LITERATURE

In many tropical arid and semi-arid parts of the world the provision of adequate supplies of water is an important limiting factor to animal production more than the supply of energy, protein or other nutrients. French (1956) reported that an animal can survive even when 30% of its body fat and protein are lost due to starvation but death results immediately up to 10% of body water is lost.

The principal sources of water for animals are drinking water, water in food and water produced by metabolism in the tissues. All these contribute to the body water pool. Water is the dietary substance required in largest amount by animals. It is an ideal dispersing medium because of its solvent and ionizing powers which facilitate cell reactions. Water takes part in body reactions as shown by the hydrolysis of proteins, fat and carbohydrates which takes place in digestion. Water is involved in many anabolic or catabolic changes in intermediary metabolism which require the chemical addition or release of water.

1.1 Water Balance

Water is lost from an animal by three main routes: in the urine, feeces and by evaporation. Degen and Young (1981) reported that high temperatures increase the requirements for water needed for evaporative cooling and high feed intakes necessitate more water intake

for digestion and excretion of waste products. To maintain a constant body water volume, water lost from the body must be balanced by an equivalent water intake. Water intake originates from water in the food, free drinking water and the water derived from metabolic reactions.

Environmental conditions (Clark and Quin, 1949) and total feed intake (Degen and Young, 1980) influence the water intake of sheep. Water balance is the equation between the sum of water drunk, water taken in with food and metabolic water formed by oxidation of food on one hand, and urine water, faecal water and water lost by evaporation via skin and lungs on the other.

Closely related to water-balance is the variation in ion-balance, especially in those ions whose excretory levels may be regulated in accordance with metabolic requirements. Tomer, Dhillon and Razdan (1969) noted seasonal variations in insensible water loss in calves and also indicated that the extent of variation depends on breed.

Bhosrekar et al. (1969) estimated the water balance in 54 lactating and 15 dry Sahiwal and Tharparkar cattle during summer and winter in India. They found an increase in water intake to dry matter ratio in both breeds during summer. Insensible water loss was high in lactating cattle and this resulted in a greater water intake in lactating than in dry cattle. Bhosrekar et al.

(1969) also noted that water intake showed seasonal variation.

Schoen (1968) reported the intakes of feed and water, water output, osmolality, Na and K contents of urine in female East African goats that were estimated in normal environmental conditions, under heat stress and when water intake was reduced by 24 or 39% of control animal's intake. They noted that the goats showed great tolerance to heat stress and reduced water intake. The tolerance to heat stress was thought to be due to resistance to the absorption of radiant heat by the shiny coat, ability to maintain a high feed intake and hence a high yield of preformed and metabolic water, a significant heat storage capacity, a reduction of water loss in urine and faeces and increase in ventilation rate. The tolerance to water restriction was thought to be due to the maintenance of a near normal feed intake, the ability to reduce water loss, especially by evaporation, and the ability to concentrate urine and reduce total cation excretion.

Maynard et al. (1983) reported that animals must receive sufficient water to balance its losses in addition to the amount required for the formation of new tissues or products. The workers further noted that the water requirement of animals vary widely according to the magnitude of the various factors which govern the losses such as species.

1.2. Species and breed differences in water metabolism

King (1979) reported field studies using tritiated water turnover, to assess dietary water intake of 212 animals throughout the year. Species of animals studied were African buffalo, dromedary camel, zebu cow, eland, small East African goat, fringe-eared oryx and Dorper sheep. He found significant differences in water intake and water turnover among species and between seasons. The oryx had the lowest daily turnover rate, followed by camel, sheep, goat, eland, cow and buffalo, when expressed in ml/litre of the approrpriate unit. The restraints imposed by traditional African animal husbandry have drastically reduced the natural ability of eland to conserve body water but had much less effect on the buffalo and oryx. King (1979) reported that the apparent reason is that though the eland is behaviourally adapted to a semi-arid environment, a specie like oryx is more physiologically adapted in view of the lower than average metabolic rate in oryx. Degen (1977) observed that a gradual reduction in water supply of Awassi sheep over a 12-day period resulted in loss of about 21% of body weight, and 25.8% TOH space. Under similar conditions, Merino ewes lost about 27.5% and 35.4% body weight and TOH space respectively. It was also reported that both breeds had reduced water content of faeces and an

increased body temperature but remained thermostable when dehydrated. Also both breeds decreased their panting rate with a reduction in water intake. He concluded that the fat-tailed Awassi can maintains its bodyweight and body fluids to a greater degree during dehydration than the German Merino and is able to replace its loss of body fluids more quickly.

1.3 Diet effect on water metabolism

Devendra (1976) reported large individual differences in water intakes, which were increased by urea on trials with Malaysia sheep fed rice straw, molasses and urea in their diets. Overall mean daily intakes were 1824ml free and 1927ml total water, 7.7 and 8.8% of liveweight.

Krishna, Razdan and Ray (1975) found that metabolic water production was higher in the winter in spite of lower dry matter (DM) intake in lactating zebu cows perhaps due to a raised metabolic rate in cold conditions. In the summer metabolic water production varied with the total digestible nutrient (TDN) intake but did not depend on protein intake. The workers also observed that the water intake was affected by nutrients (energy and protein). Insenisble water loss was higher in summer and was also significantly affected by TDN in both seasons and by protein in summer.

Total feed intake (Forbes, 1968) influence the water intake of sheep. Shkolnik et al. (1972) studied water requirements in black Bedouin goat of the Negev desert and found that it varies with the diet type and combination. Maloiy and Taylor (1971) compared the water requirements of goats and haired sheep in the arid northern region of Kenya and observed that goats required less amount of water than sheep. Khan et al. (1978) studied the Barmer goats in the Rajasthan desert and noted that the water intake varies with the protein content of the diets. Rumsey et al. (1979) reported variation in water intake with different diets in bullocks. Krishna et al. (1976) reported dietary effects on water intake of Tharparkar and Sahiwal cows while Devendra (1976) studied influence of plane of nutrition on water intake of Malaysian sheep. Singhal and Mudgal (1981) reported dietary effects on water intake of growing Beetal goats.

1.4 Physiological changes in water metabolism

Yangil and Berlyne (1977) reported that dehydration in camels led to rise in blood glucose level and it also caused blood insulin to fall. Macfarlane, Howard and Morris (1966) reported on the effect of shearing on Merino wethers in the dry subtropical region of Queensland, during a period of sunshine with maximum temperature between 36° and 33°C. The content, distribution and turnover of water were estimated before and after shearing. They found no significant change

in total body water while the thiocyanate space increased by 12%, the plasma volume by 17%, and the plasma proteins were diluted by 17% after shearing. Water turnover rose from 81.5 to 159ml per kg per 24h. They estimated that an average increment of 1550Kcal per 24h in heat load from insolation occurred as a result of the removal of fleece during exposure to summer sun.

Vattonen and Eriksson (1977) reported that water at 10% of bodyweight averaging 6.5litres was introduced into the rumen of 2 female reindeers. These workers found that water diuresis began within 30min; the peak lasting for only 40min, was reached quickly and thereafter urine flow declined rapidly. Vattonen and Eriksson (1977) also noted that urea and electrolyte excretion were little affected. When the reindeer were deprived of water for 48h, they lost 20% of their bodyweight. Urea concentration in plasma and urine rose during dehydration and urine flow rate after 2 days of water deprivation decreased to half the original value. Barmer goats deprived of water for 4 days in the autumn, maintained plasma and extracellular fluid volumes and lost water from the gut and cells (Khan, Sasidharan and Ghosh, 1979).

1.5 Water Estimation

Searle (1970) estimated tritiated water space in female and castrated male sheep of ages ranging from

3 days to 18 months. When the sheep were killed and water, fat, protein, ash and energy were estimated in minced carcasses, it was observed that (up to 9 months of age) water decreased from 77.2 to 73.0%, protein increased from 18.8 to 21.0% and ash from 3.9 to 5.8% of fat-free empty bodyweight. Searle also noted that there were close correlations between tritiated water-space and chemical components of carcass.

Hansard (1964) studied pigs, cattle and sheep placed in metabolism units for 10 to 15h. He administered intravenously 1 to 2g antiprine, 25 to 50 mc antipyrine I^{-131} or 2 to 3 mc tritiated water (TOH) per 100lb bodyweight. He observed that the mean rates of disappearance of antipyrine from the blood in the pigs, cattle and sheep were 45, 23 and 28% per h. He also noted that in all three species, no significant amount of I^{131} from antipyrine was excreted in faeces or retained in the digestive tract, but significant amount of both antipyrine itself and TOH were found in both tract and faeces. By all 3 methods, average amounts of total body water were calculated to be 65.1 and 46.2% of bodyweight in young and mature pigs, 69.9 and 50.2% in beef cattle, 62.7 and 56.5% in sheep.

Ranjhan et al. (1982) reported that native Muzaffarnagri and crossbred sheep in India did not differ significantly in body composition. The water turnover rates were not significantly different between breeds within the same season, but a significant difference was observed between the two seasons (Winter and Summer). They found that water turnover and water requirement were lowest in goats followed by sheep, crossbred cattle and buffalo when expressed as $ml/kg^{0.82}/d$. The latter also observed that metabolic water production was 10% of the total water input in buffalo and crossbred cattle, but was more in sheep and goats in both seasons.

1.6 Water turnover

Over 99% by number of the molecules present in a ruminant are water (Macfarlane and Howard, 1972). The powerful effects of solar radiation on water demand in arid and semi-arid areas are integrated with those of air temperature and food supply. Water requirement is influenced by age, environmental temperature, food supply, lactation and behaviour (Macfarlane and Howard, 1972). Tropical and sub-tropical climates are known for high ambient temperatures, irregular and scanty rainfall along with low quality and quantity of available forage. Such environments exert nutritional stress on the ruminants inhabiting the area. These workers also reported that the turnover of water by ruminants is closely related

to the moisture content of pasture plants. In the tropical summer there may be low rates of water intake when dry vegetation is eaten but rain in the summer rapidly increases water turnover when lush vegetation are abundant. Macfarlane et al. (1966) observed that sheep do not need to drink when pasture carries 60-70% water. Shkolnik (1972) reported that Bedoiun goats were sometimes watered only once every four days even during the hottest part of the summer.

In studies by Anand et al. (1966), mature Rambouillet and Rambouillet x Suffolk ewes from 2½ to 14 years old were given 1.13kg of dried Lucerne pellets and salt daily while water was provided ad libitum. Tritiated water was injected into each animal through one jugular vein and blood samples were taken from the other at 4-h intervals for the first 12h and then every 12h up to 7 days. The latter found that the mean total body water was 54.6 ±1.8% of liveweight and biological half-life of tritium was 4.4 to 7 days with an average of 5.4 days. Mean daily intake of water, total water loss and urine production wwre 66.8, 72.7 and 27.1ml per kg live-weight. Daily water intake by drinking was 92% of total water loss. , while urine formed only 37.2% of total loss or 40.6% of total intake. Degen and Young (1981) estimated the total body water and total water turnover using tritiated water injected into weaned Suffolk crossbred lambs each weighing 20kg in temperature chambers at 0°, 10°, 20° or 30°. The

latter noted that turnover, evaporative water loss and DM intake were influenced mainly by environmental temperature, Percentage water in faeces was influenced mainly by amount in feed; losses in urine were not affected by environmental temperature or amount of feed.

Aggrey (1982) studied the effect of seasonal changes on water content and water turnover of cattle, sheep and goats on pasture under humid tropical conditions, using tritium dilution technique. Aggrey (1982) reported that total body water was significantly lower in the dry season than in the wet season. The latter also noted that in all seasons water turnover was highest in cattle, followed by sheep and then goats. Aggrey (1982) concluded that the goat would be a more suitable animal for production under dry conditions than cattle and sheep. Kamal (1982) used the tritiated water dilution technique to determine the total body water (TBW) and water turnover rate (WTR), in water buffalo, Red Danish cattle, fat-tailed Ossimi sheep, crossbred Nubian - Bedoiun goats and camels. The later reported a significant effect of species on TBW and WTR.

Springell (1968) reported that the total body water (TBW) and its distribution in the body of the animal can be used as an index of the condition of the animal as it is proportional to the body solids. Macfarlane and Howard (1966) and Degen (1977) noted that water turnover, which is genetically determined, is also affected by environmental conditions such as ambient temperature, type and availability of food and water and the activity of the animal. Water content and its turnover may

be related to the adaptation of livestock to a tropical environment (Springell, 1968). Macfarlane et al. (1974) and Bird (1984) predicted body water content and body composition using tritiated water space (TOH). Panaretto and Till (1963) worked on body composition in vivo of mature goats using TOH space. Gharaybeh et al. (1968) indicated that crossbred animals differ from pure breeds both in body composition and water turnover rate.

1.7. Water Deprivation

Khan, Sasidharan and Ghosh (1978) reported the effect of water deprivation on Barmer goats grazing and browsing on natural vegetation for 8 hours a day in the Rajasthan desert. Two groups of 6 castrated male goats 18 months old were kept on the experiment during summer, from April to June and in the post-monsoon period from September to December. The control groups were watered daily and drank an average of 7.59 litres/100kg liveweight daily. The second group were given a quarter of the intake by the controls. The experimental animals showed no loss of appetite or weight. During May and June when the maximum temperature was 40°C, the control group gained 2.7% of initial weight and the restricted group gained 1.67%.

Blair-West et al. (1979) reported studies in which the water intake of 4 Merino ewes was restricted for 8 to 15 days to produce a minimum loss of 10% bodyweight

while they continued to eat their normal ration of feed. The animals were then given access to water or 10ml potassium chloride for 2h. The latter observed that water restriction increased plasma renin and vasopressin concentration. When given free access to water, plasma renin increased further but urine flow rates did not return to normal for at least 6h following re-introduction of free-access water.

More and Sahni (1978) reported on the water requirements of weaned chokla lambs recorded up to 6 months of age. Thereafter the experimental animals were divided into 3 groups and given water once every 24h, once every 48h during winter, or once every 72h during summer. In the same work, they observed that; water deprivation during winter did not affect weight gain but summer deprived lambs lost 16.4% of liveweight. Overall water intake of control and deprived groups was 2.4 and 3.7 litres daily. When given on alternate days in winter, water consumption appeared to be compensated for by the deprived lambs taking up to double the quantity of that drunk by controls. More and Sahni (1976) noted that haematocrit values did not indicate significant dehydration in either season and there was no decrease in plasma volume extracellular fluid or body water caused by deprivation of water for 48h in winter. In summer, water deprivation for 72h significantly increased body fluid volume.

Narinder and Taneja (1978) reported on the effect of water deprivation under arid conditions on two groups of Marwari ewes grazing natural pasture in India. The control group had free access to water and the experimental group had no drinking water. It was found that, during summer, the deprived group lost 34% of liveweight in 3 days, and in winter they lost a similar percentage of weight in 36 days. Average air temperature was 18.5°C in winter and 33.3°C in summer resulting in increased water requirement in the summer. Succulent desert plants also provided a source of moisture in winter up to 70.4%, while in summer moisture content was only 20.5%. Narinder and Taneja (1978) also observed that packed cell volume and rectal temperature were higher in deprived than control sheep and higher in summer than in winter at maximum weight loss.

The latter also found that when water was offered after deprivation sheep drank 17 litres in summer and 5 litres in winter on the first day and all weight loss was regained in 31 days during summer and in 19 days during winter.

More and Sahni (1981) reported studies made at Avikanagar on chokla ewes grazing for 8 to 10h a day on natural pasture without supplement. There was no rainfall in winter and spring and mean relative humidity fell to 18.4% at 1500h in spring. The

ewes, in 4 groups were allowed water once in 24, 48, 72 or 96h; 7 ewes from 1st, 3rd and 4th groups were mated first in spring before the trial and again in winter, so that they lambed in the monsoon and in the following summer. They found that all the ewes watered once in 24 or 72h lambed successfully in the first cycle but 4 of the ewes watered once in 96h aborted in the first summer; in the second cycle, with pregnancy in winter and spring, all lambed successfully. A singificant increase of water intake in the 3rd month of pregnancy was also observed. Ewes watered once in 72 and 96h drank up to 32% of their bodyweight in 2 to 3min, but mean daily intakes were less by 2 to 5% of bodyweight than those of ewes daily. These workers also noted that non-breeding ewes drank less than those in late pregnancy or lactation. Those ewes were watered every 48h drank as much as those watered daily. Pregnant ewes watered once in 72h or 96h lost weight; those which aborted lost about 34% of bodyweight in May, the hottest month, whereas those that lambed lost about 26%. In the second breeding season it was found that the water-deprived ewes lost only about 15% of bodyweight, but up to 20% during the lactation period in summer.

In studies by More, Singh and Sahni (1976) newly weaned chokla lambs from 90 days of age, in 2 groups each were given water to appetite every midday for 6

months or at intervals of 48h for 3 months followed by 72h for the next 6 months. For 5 months the lambs grazed uncultivated grasses and shrubs for 8 to 10h daily and in the last month they were fed on cowpea hay in stalls. The maximum and minimum temperature reported for January, were 23.0°C and 5.3°C. Daily maximum temperature then increased to 37.8°C in June, At the end of the trial, lambs watered daily weighed 23.7kg and the others weighed 18.8kg. They further observed that deprivation of water reduced weight of gastrointestinal tract, liver and skin. Water deprivation increased dressing percentage from 41 to 45% but the chemical composition of longissimus dorsi was not affected.

Ghosh, Khan and Abichandani (1976) reported on the effects of 24h and 48h water deprivation of glomerular filtration rate (GFR), and on blood and urine electrolyte levels in Marwari sheep. The latter found that bodyweight, urine volume, GFR and erythrocyte Na concentrations fell considerably due to dehydration. Plasma Na and urinary K concentrations remained unaffected. While plasma K appeared reduced, the K in red blood cells increased after 48h of water deprivation. The most remarkable response reported was in the concentration of urinary Na which rose to more than double the normal.

Purohit, Ghosh and Taneja (1974) found that 50% water restriction for 21 days resulted in a significantly decreased urine volume, faecal water and transfer function of kidney while urine electrolytes increased significantly in Marwari rams. When restricted sheep were again allowed free access to water, urine volume recovered within 24h.

Clark and Jay (1975) reported a 4-year study with 3 generations of Romney ewes which was designed to measure intake of drinking water and to compare growth and reproduction with and without access to drinking water. The latter found that daily water intake was generally small and exceeded 4.5 litres on only two ambient temperature. The same workers also noted that sheep are adapted to absence of drinking water during periods when the normal requirement is low. Gordon (1965) found that the time spent ruminating by sheep was reduced by deprivation of water, while feed intake was also reduced by 46%.

Umunna et al. (1981) reported studies in northern Nigeria during the rainy season and end of the dry season respectively in which Yankasa sheep were given either a high-roughage or a high-concentrate diet. Water was given once in 24, 48, 72 or 96h. Free water intake decreased linearly and significantly as the period of water deprivation increased but feed intake was not similarly affected. The latter

also found that there was a marked decrease in liveweight gain and consequently an increase in feed intake/kg gain. In the metabolism study, there was a tendency for nitrogen (N) in faeces and urine, and moisture in faeces to decrease while mean retention of N and digestibilities of N increased with increasing period of water deprivation. They also noted that rams given water once in 72 or 96h were inactive and two rams died of severe dehydration in the group with a high-concentrate diet given at the end of the dry season.

1.8 Water Intake

In studies by Taneja and Abichandani (1967) in Rajasthan using Marwari wethers that were 2 years old; intake of drinking water was measured daily from February to June, when environmental temperatures ranged from 74° to 107°F at various relative humidities. The workers found no significant relation between intake and relative humidity.

Wilke, Smith and Janovsky (1961) reported that lactating Saanen goats 14 to 18 months old were given straw treated with sodium hydroxide, either alone or in a complete mixed feed. DM intake was more closely related to liveweight. When untreated or NaOH - treated maize straw were given to appetite, it was found that NaOH treatment increased the water intake by more than 50%. With complete mixed

diets, water intake was increased when the diet contained 60% NaOH treated maize straw (5% NaOH) or when the sodium intake was 18mg/g feed. Wilke et al. (1981) also noted that surplus Na was excreted via a higher concentration of Na in urine and a greater volume of urine.

Stephenson et al. (1980) reported that the effect of heat stress on milk production, feed intake, water intake, urine output, growth rate of lambs and plasma prolactin concentrations were determined in ewes and their lambs. They found that bodyweight gain was similar in both stressed and unstressed lambs. Feed intake was reduced by heat stress in the climatic chamber but not under natural conditions. These researchers also found that water intake and plasma protein concentrations were increased in heat-stressed ewes. Urine output accounted for 67 and 80% of the water plus milk intake of unstressed and heat stressed lambs, respectively at 5 to 6 weeks old. The latter would indicate the importance of providing water to lambs during grazing in tropical regions.

Clark and Quin (1949) reported that on a ration of poor quality grass hay, sheep were found to maintain their normal intake of water when allowed to drink for one hour only every second day. When given water at 72h and 96h intervals, the total intake was decreased to 63 percent and 54 percent of the normal, respectively.

The consumption of lucerne hay was markedly suppressed by lack of water even during the first 24 hours of thirsting. Clark and Quin (1949) also observed that sheep on lucerne hay receiving water only twice weekly still gained in body weight. This gain was, however, accelerated when water was constantly available.

Macfarlane, Morris and Howard (1958) reported that Merino sheep required more water in summer, on the average 12 times as much as in winter, when they took 7.3ml/kg/day. Also, they reported that water intake was closely related to respiratory rate.

When water requirements was estimated, during 2 seasons for buffalos, Holstein x Haryana cattle, Suffolk x Muzaffarnagari sheep and Barbari goats, Ghosh et al. (1980) found that there were significant difference in the water requirement and water turnover between seasons and between species. Water turnover and water requirements were least in goat followed by sheep, cross-bred cattle and buffalo when expressed as $ml/kg^{0.82}$ day. Metabolic water production in winter was 1.16, 3.54, 0.45 and 0.13 and in summer 2.25, 2.00, 0.38 and 0.12 litre/day in buffalo, crossbred cattle, cross-bred sheep and goat respectively. Metabolic water production was 10% of total water input in buffalo and cross-bred cattle, but was more in sheep and goats for both seasons.

Bond, Rumsey and Weinland (1976) reported that the feeding and drinking patterns of bullocks were not altered before, during and after deprivation of feed, water or both when three sets of monozygotic twin beef bullocks were given free access to water and fed ad libitum on a 30% forage diet, and 88% forage diet and a no-forage diet in 3 trials. These researchers also found that water intake was much reduced when bullocks were deprived of a high-roughage diet but not when they were deprived of non-forage diet. Feed intake was reduced about 50% on each type of diet when water was withheld. These workers therefore concluded that when feed, water or both were withheld from cattle for up to 2 days and then re-offered the same feed, there was minimal changes in their intake patterns.

Phillips (1960) showed that water intake of cattle depended on food intake and body weight. Thickett et al. (1981) reported a significant correlation of both liveweight gain and pellet intake with water intake of British Friesian bull calves. They found that for each extra litre of water consumed per day, there was an extra pellet intake of 0.082kg and an increase in liveweight gain of 0.056kg.

The water requirement for individual animals depends on the composition of the animals diet (Crampton and Harris, 1969).

Bass (1982) noted that the drinking pattern of wether sheep was directly related to the type of food offered and its distribution throughout the day. Rumsey et al. (1979) reported that water intake of bullocks was dependent on diet. Cunningham et al. (1964) reported on the dependence of water intake of lactating cows on environmental temperature; while Taneja and Abichandani (1967) reported no significant relation between water intake and relative humidity in Marwari wethers. Morrocks and Phillips (1961) reported that the water intakes of shorthorn were significantly higher that those of the Borans. Krishna et al. (1976) found that water intake of cattle was highly correlated with DM intake. Devendra (1976) observed that water intake of Malaysian sheep was significantly affected by diet.

The results of previous workers have shown the importance of water in animal production. Water requirement by a ruminant animal depends on many factors such as environmental conditions, total feed intake, feed type and the physiologic state of the animal. In tropical countries, high environmental temperature influences water intake of these ruminants animals especially during the dry season when there is no green fodder. The physiologic state of the female animals also influence water requirement. Since there is paucity of data on water requirements of Nigerian indigenous sheep and goats, it was necessary to carry out this study.

CHAPTER II

MATERIALS AND METHODS

2.1 Location

The investigations were conducted at Ahmadu Bello University Farm, located on Shika-Sokoto road, Zaria. The farm location is situated at 11° N latitude and 640m above sea level. The studies were conducted during the three recognised seasons of the year : March-April (hot, dry season), November-January (cold, dry season) and June-August (wet season). Daily and weekly meterological data were obtained from the Institute for Agricultural Research, Samaru (Table 1).

2.2 Management of experimental animals

The animals were fed and watered in individual pens housed under a common roof. The animals were fed on hay (*Andropogon gayanus*) and concentrate consisting of a mixture of maize and cottonseed cake (C_1 and C_2) (tables 2 and 3). The animals were individually fed daily and feed refusals were weighed to determine intake. Measured amounts of clean water was given to the animals in metal pails and they were allowed to drink to appetite and the water left was measured to determine actual amount of water intake. The animals were weighed biweekly to monitor growth.

2.3 Measurement of physiologic Parameters

Jaw movement data were obtained by visually observing the experimental animals and counting the number of times the jaw moved in a minute during chewing.

Table 1: Climatic conditions+

	Average Daily Rainfall (mm)	Temperature (°C) Maximum	Minimum	Relative humidity(%) Maximum	Minimum
Dry hot season (March-April)	Nil	39	21	67	13
Wet season (June-August)	6.28	28	17	82.1	71
Dry cool season (October-January)	Nil	30	15	39	17

+(Samaru I.A.R. Weather Station Report)

Table 2: Percentage composition of the concentrate mixture

Ingredient	Composition (%)	
	C1	C2
Maize	72.2	60.16
Cottonseed cake	24.1	36.09
Salt	2.0	2.0
Bone meal	1.5	1.5
+Vitamin-mineral Premix	0.25	0.25

+Vitamin-mineral Premix used is ZOODRY VM 702 and it contains per kg diet: vit. A 25,000 I.U., vit D_3 27,500 I.U., vit. E 25mg, Magnesium (mg) 250mg, Magnanese (Mn), 125mg, Iron (Fe) 200mg, Zinc (Zn) 112.5mg, Copper (Cu) 15mg, Iodine (I) 6.5mg, Cobalt (Co) 2mg.

C1 - Fed to pregnant, non-pregnant and male animals

C2 - Fed to lactating ewes.

Table 3 : Analyzed composition (%) of the concentrate meals and hay (DM basis)

	Hay	C1	C2	Maize
Crude protein (CP)	4.10	16.4	18.0	9.4
Ash	9.0	5.0	5.8	4.0
Ether extract (EE)	2.0	4.0	4.98	3.4
Crude fibre (CF)	39.1	5.5	5.9	2.7
Nitrogen free extract (NFE)	37.80	61.30	59.32	69.5

Energy per g of diet = 3870.32 cal/kg

Rectal temperature was measured by inserting clinical thermometer into the rectum of each restrained experimental animal for 2 minutes. The thermometer was cleaned using cotton wool soaked in methylated spirit between animals.

Respiratory rate was obtained by counting the movements (per minute) of the thoracic cage of the experimental animals.

Pulse rate was obtained by counting the pulse on the femoral vein of the experimental animal.

2.4 Blood Collection, handling and Storage techniques

Blood was obtained from the experimental animals through the jugular vein using sterile 19G needles. The venous blood samples were put into labelled plain small pyrex tubes for serum while the tubes contained anticoagulant (ethylene diamine tetracecetic acid) (EDTA) in the case of samples meant for plasma. The tubes were then covered with fitted stoppers. Samples meant for plasma were agitated gently to mix the blood with the anticoagulant. The blood samples were kept at $4^{o}C$ for 24h before centrifuging at 3500 rev/min for 15min. Blood samples meant for plasma were centrifuged immediately after collection at 3500 rev/min for 15min. The plasma and serum collected were stored at $-32^{o}C$ until analysed.

2.5 Estimation of Blood Parameters

Estimation of blood parameters, packed cell volume (PCV), haemoglobin (Hb), Red blood cell (RBC), White blood cell (WBC), Mean corpuscular haemoglobin concentration (MCHC), mean corpuscular volume (MCV) and mean corpuscular haemoglobin (MCH), were done according to Brown (1980).

Serum total protein was determined by the Biuret method (Coles, 1967). Electrophoresis of serum samples was carried out according to the procedure outlined for a Micro-zone Electrophoresis system (Beckman Instruments, Clinical Instruments Divison, Fullerton, Calif, USA). The albumin, α_1 - , α_2-) β- and γ- globulin fractions were run on cellulose acetate strips using Beckam B - 2 buffer at pH 8.6 and u = 0.075. The electrophoretic strips were fed into a Beckman R 110 Densitometer, and estimates of each protein fraction obtained based on the total serum protein determined as stated earlier.

Serum magnesium was analyzed using an atomic absorption spectrophotometer, Perkin-Elmer 290B (Perkin Elmer, Norwalk, Conn, USA), according to the procedure outlined for determination. Serum sodium and potassium were determined by flame photometry. Serum chloride was analyzed as outlined by Coles (1974).

2.6 Statistical analysis

The statistical analysis of variance of various parameters was done as per the methods of Steel and Torrie (1960), and treatment differences determined by the orthogonal comparisons of means as outlined by Snedecor (1959).

Experimental 1: Water balance of Maradi goats and Yankasa sheep.

Four Maradi bucks with a mean weight of 20kg and 4 Yankasa rams each weighing 25kg were used in the study. The animals were put in metal metabolism cages for a precollection and adjustment period of 21 days during which time they were given free access to drinking water and feed (table 1 and table 2). The animals were fed hay and concentrate at a ratio of 60:40. The adjustment period was immediately followed by a 14-day collection period during which feed intake, water intake, faeces voided and urine output were measured. The animals were dressed with harness bags for collection of faeces. Urine produced was collected in plastic pails placed under the metabolism cages. The plastic pails contained 25ml of toluene to prevent the evaporation of the urine and 25ml of 50% H_2SO_4 to trap the nitrogen in the urine. The animals were weighed biweekly. Serum obtained once a week from the blood of the animals were analysed for sodium and potassium. The moisture content of the feed and faeces were determined (A.O.A.C. 1970). A sample of fresh faeces was collected daily, and the faecal moisture content was determined by drying the fresh material at 105^{o}C constant weight. Total daily faecal water loss was then calculated from the total daily faecal output. Pre-formed water in feed was determined after calculating the water content of samples of feed

dried at 105°C to constant weight. Metabolic water gained was estimated daily by calculating the oxidation water obtainable from one gramme of feed and multiplying this figure by the difference between dry food eaten and dry faeces voided (Schoen, 1963). Evaporation water loss was calculated by substracting the sum of faecal and urinary water loss from the water intake, pre-formed water and metabolic water.

Samples of urine were collected daily per animal and stored in polythene bottles at 4°C until analysed for sodium and potassium using the flame photometer.

Experiment 2: Breed differences in water metabolism of penned indigenous sheep and goats.

Two breeds each of sheep and goats were used namely Yankasa and Ouda sheep and Sahel and Maradi goats. Sixteen animals (4 of each breed) were used in the study. The animals were pen-fed measured amounts of native hay (Andropogon gayanus) and concentrate containing 16% crude protein (tables 2 and 3). Blood samples of the animals were collected once every 3 weeks to determine the following : PCV, Hb, WBC, MCHC, MCV, MCH, Plasma Na^+, K^+ Mg^{++} and Cl^-, Blood urea nitrogen, serum albumin, total protein and serum alkaline phosphotase. The feeding trial lasted for 63 days and the experiment was conducted in the hot, dry season of the months of March, April and early May. At the end of the 63 days the animals were deprived of feed and water for 18h, following which tritiated water TOH was injected. The venous blood of the animals were sampled immediately prior to TOH injection (blank).

Sterile tritiated water diluted with physiological saline was injected intramuscularly at a single dose rate of 10-15 Ci/kg[1] body weight. The animals were then kept without access to feed and water for a period of 48h. Venous blood samples were taken from each animal at six-hourly intervals for the next 72 hours after which the animals were given limited amount of

[1] $1Ci = 3.70 \times 10^{10}$ Bq

feed and water. On subsequent days daily blood sample was taken until the 8th day after TOH injection. Soon after collecting the last blood sample, the animals were weighed and slaughtered for direct determination of body composition. Five ml of blood were collected from each animal at each blood sampling. Disodium salt of ethylene diamine tetraacetic acid (EDTA) (0.8mg/ml of blood) was used as the anticoagulant.

The blood samples were centrifuged at 3500 revolutions/min for 15min. The plasma collected were stored at $-32^{o}C$ until preparation for counting.

To determine the amount of radioactivity in plasma, one millilitre of 20% trichloroacetic acid (TCA) was added to 1ml of plasma to denature the proteins; the test tubes were then centrifuged for 10 minutes and the protein-free supernatant removed. Samples were prepared for counting in vials by mixing 0.50ml of deproteinised plasma with 10ml of toluene based liquid scintillation cocktail.

Samples were counted in duplicates together with blanks and standards in single well-type liquid scintillation counter (LSC 2 Neclear Enterprises). Quenching was corrected for by the channels ratio method. Blanks were similarly prepared by treating pre-injection blood samples as described above for the samples. Standards were prepared by diluting the dose

solution of TOH 1:1000 and 0.2ml of this was counted in triplicate as above.

The rate constant (K) for the disappearance of radioactivity from plasma is the slope of the regression line obtained by plotting the logarithm of the disintegration counts of samples taken over the period of 8 days (In St) against time (t) based on the following equation:-

$$\text{Ln St} = \text{ln So} - Kt$$

So is the value of St at the time equal to zero when isotopic water was administered.

The biological half-life of tritium was determined by substituting K value in the following equation:

$$K = \frac{0.693}{\text{Half-life}}$$

TOH space was calculated as described by Springell, 1968; Ranjhan et al. 1982 from the following equation.

$$\text{TOH space (litres)} = \frac{\text{Standard count (dpm) x dose (ml)}}{\text{Sample courts (dpm)}}$$

The water turnover rate was calculated as the product of the TOH space and the rate constant (K) for the disappearance of radioactivity from plasma. From the results of the direct slaughter technique and the indirect TOH dilution technique, prediction equations were formulated to determine body composition in the living animal from TOH space. Total body water was calculated by using the factor 0.85 x TOH space (Kings, 1977, Ranjhan et al. 1982).

Determination of body composition

The body composition of the experimental animals were determined directly using the direct slaughter technique method described by Panaretto and Till (1963). After the animals were slaughtered, the alimentary tract was removed and the gut contents homogenized and analysed for moisture content. The half carcass obtained after dressing the carcass and halving through the back bone was divided into different commercial cuts and each cut was chopped into small pieces with a heavy chopper. A portion of this chopped mass from each cut was pooled, together with similar portions of chopped mass from skin, head, feet and entire gut (without contents) and various internal organs. The pooled mass was then homogenized by chopping and pounding with an iron pestle in a mortar. The minced mass thus obtained was analysed for moisture, protein, fat and ash contents as per the methods suggested by Sebranek (1976).

Experiment 3: Effect of age and sex on the water requirement of penned sheep and goats

Twenty Maradi goats and twenty Yankasa sheep were used in this study. The animals were 10 males and 10 non-pregnant, non-lactating females for each specie. Five each of the males and females were about 12 months old while the other 5 were about 24 months old. The animals were watered daily using clean metal pails. The goats were fed weighed quantities of concentrate (C_1 Table 2) and roughage in the ratio of 40:60. The study lasted 50 days.

The animals were alloted in four (groups) treatments of 5 animals per group for each specie, that is, 4 groups of sheep and 4 groups of goats:-

Group 1, 5 male, 1 year old

Group 2, 6 male, 2 years old

Group 3, 7 female, 1 year old

Group 4, 8 female, 2 years old

Based on feed requirements, the one year old goats were given 166g concentrate daily while the 2 years old received 208g daily. The 1 year old sheep had 208g while the 2 years old got 292 daily.

Experiment 4: Seasonal variations and influence of intermittent watering on grazing Yankasa sheep.

Twenty male Yankasa sheep divided into 4 groups of 5 rams were used in this study. The animals weighed averagely 20kg and they were 15 months old. They were selected from the sheep flock on the Ahmadu Bello University Farm. The animals were grazed for 6 hours daily for a period of 50 days during which they were subjected to intermittent watering. Watering intervals adopted were treatment 1 - once in 24h (daily), treatment 2 - once in 48h, treatment 3 - once in 72 and treatment 4 - once in 96h. The animals were given on the average 250g of concentrate (C_1 on Table 2) each day after grazing. The animals were watered according to their assigned treatments after grazing. This experiment was carried out in the wet season (June, July, August) and also repeated in the hot, dry season (March - April) to determine seasonal variations using another set of 20 Yankasa male sheep. The animals were not allowed to drink on the field when grazing during the rainy season.

The animals were weighed biweekly to monitor growth. The uncultivated pastures grazed by these animals were sampled twice a week to determine the proximate composition using A.O.A.C. (1970) methods of analysis (table 4). Physiologic parameters namely

Table 4: Mean proximate analysis (%) of pastures grazed by experimental animals (DM basis)

	Dry season pasture	Wet season pasture
Dry matter	93.1	20.9
Ash	9.4	10.6
Ether extract	1.6	5.3
Crude fibre	38.5	23.6
Nitrogen free extract (NFE)	47.4	47.8
Crude protein	3.0	12.7

jaw movement as an indication of rumination , rectal temperature in later afternoons, respiratory rate and pulse rate were determined as discussed earlier.

Blood was obtained from the animals forthnightly through the jugular vein. The blood samples were used to determine the plasma minerals, serum, albumin, alkaline phosphatase and blood urea nitrogen, PCV, Hb, RBC, WBC, MCHC, MCV, MCH.

Experiment 5: Influence of diet type on water intake of sheep and goats.

Sixteen Yankasa rams weighing averagely 22kg and 16 Maradi male goats weighing on the average 15kg were used in the study. The Maradi goats were purchased from the local markets and then quarantined for 60 days. The animals were treated for intestinal parasites with Thibenzole (Merck Sharp and Dohme, MSD). They were also dipped against external parasites with phizone(R), and then all the goats were treated with long acting terramycin (Ffizer) to prevent goat 'kata'. During the quarantine period and goats were kept indoors and fed hay (Andropogon gayanus predominantly) and cotton seed cake/maize concentrate mixture. The goats were taken out once in 2 days for grazing to allow them adjust gradually from their previous management of unlimited roaming, grazing and browsing. Their grazing time was then gradually reduced until finally stopped. They were kept indoors for 2 weeks prior to the start of the study to allow them adjust to pen management.

The animals were randomized into 4 groups of 4 sheep and 4 goats each. Four diet types were tested in 4 treatments.

treatment 1 - hay only

treatment 2 - hay + whole maize

treatment 3 - hay + milled maize

treatment 4 - hay + concentrate mixture

Concentrate mixture was made up of maize and cottonseed cake (Table 2). Table 5 shows the chemical composition of the feeds on dry matter basis. The animals were fed to appetite once daily in the morning.

Table 5: Ghemical composition (%) of the diets fed. (DM basis)

	Hay + Maize	Hay + Concentrate
Crude protein (CP)	6.22	9.02
Ash	7.00	7.40
Ether extract (EE)	2.56	3.12
Crude fibre (CF)	24.54	25.66
Nitrogen free extract (NFE)	50.48	47.2

Experiment 6: Response of Yankasa ewes under various physiologic states to water deprivation

Thirty-six Yankasa ewes were used for the study out of which 12 were 3-months pregnant, 12 were open (non-pregnant) and non-lactating and the other 12 were lactating and not pregnant. The animals were housed in individual pens under a common roof. The animals were subjected to 3 forms of watering intervals; daily (groups 1, 2 and 3) (24h intervals), 48 hourly (groups 4, 5 and 6) and 72 hourly (groups, 5, 7, 8 and 9). Within each physiological class (pregnant, open and lactating), the ewes were randomly allocated to the 3 watering regimes. Thus, under each watering regime 4 ewes of each physiological group were present, that is 4 pregnant, 4 open and 4 lactating.

The experimental diet (Tables 2 and 3) which comprised of hay and a protein supplement were fed at the ratio of 60:40 respectively.

The lactating ewes were hand milked at 8a.m. at forthnightly intervals to determine average milk yield per day. Lambs were withdrawn from the ewes a night previous to the milking day, and then returned to their dams. Milk samples were also analysed for total solids, water content, fat, ash and crude protein in the laboratory using the A.O.A.C. (1970) method of analysis.

Physiologic parameters namely jaw movement, rectal temperature in late afternoons, respiratory rate and pulse rate were measured as previously described.

Blood was obtained from the ewes forthnightly. The blood samples were used to determine the plasma minerals, serum proteins, alkaline phosphatase, blood urea nitrogen, PCV, Hb, RBC, WBC, MCHC, MCV and MCH.

The study was conducted towards the end of the rains and in the early dry, cool season (September - October) lasting 50 days.

Experiment 7: Effect of feed restriction on water requirement of sheep.

Twelve Yankasa rams weighing about 19kg on the average were used for the study that lasted 50 days (trial 1). The animals were randomly distributed into 3 treatments of 4 animals each. The treatments were:

i. daily feeding (24 hourly)
ii. 48 hourly feeding
iii. 72 hourly feeding

The experimental animals were dipped against ectoparasites using Pfizona and dewormed using Rafoxanide (Ranide)(R) before the beginning of the experiments. The animals were given hay and concentrate mixture (table 2) made up of maize and cotton seed meal in the ratio 60:40. The animals were given feed according to the treatment and feed refusals weighed daily. Blood samples were collected through the jugular vein every forthnight to determine the following: serum albumin, blood urea nitrogen, plasma-sodium, potassium, magnesium and chloride. Total protein, MCV, Hb, MCH, PCV, WBC, RBC, MCHC and alkaline phosphatase were determined as described. Pulse rate, respiratory rate, jaw movement and rectal temperature were measured every day throughout the experimental period.

The study was repeated using another set of 12 Yankasa rams weighing averagely 20kg for a period of 50 days (trial 2). Animals in treatment 1 were given full feed of 800g dry matter (DM) to allow for 10-15% refusal while those in treatment 2 got ½ feed of (400g DM) and those on treatment 3 had a ¼ of 200g DM daily. The animals were watered daily. As in trial 1, blood parameters and physiological parameters were also measured. The animals were weighed biweekly to monitor growth. The study was conducted in October to January (cool, dry season).

Experiment 8: Effect of feed management on water intake of Yankasa sheep and Maradi goats

Two trials were conducted, the first was to study the effect of concentrate to roughage ratio on water consumption of sheep and goats (trial I), while the second trial was carried out with Yankasa sheep to study effect of feed processing on water intake (trial II). In trial 1, 16 non-pregnant, non-lactating Yankasa ewes and 16 non-pregnant, non-lactating Maradi does aged 15 months wered used. The animals were randomly allocated to 4 treatments of 4 goats, 4 sheep each. The 4 treatments were as follows:-

treatment 1 40:60

treatment 2 60:40

treatment 3 30:70

treatment 4 70:30

percentage ratios of concentrate to roughage in the diets fed to the animals. The study lasted 50 days.

In the second trial (trial II) 16 Yankasa non-pregnant, non-lactating ewes aged 15 months each weighing 20kg were used. The animals were randomly distributed into 4 treatments of 4 animals each and fed individually viz

Trt. 1 - Long hay + milled concentrate
Trt. 2 - chopped hay + milled concentrate
Trt. 3 - Long hay + unmilled concentrate
Trt. 4 - Chopped hay + unmilled concentrate

All the animals in the 4 treatments were given 650g DM daily for 50 days consisting of 40% concentrate and 60% hay. Water and feed intake were measured daily and body weight measurements were done every forthnight. The studies were conducted in the cool, dry season.

CHAPTER III

RESULTS

Experiment 1

3.1: WATER BALANCE OF MARADI GOATS AND YANKASA SHEEP

Average daily gain in body weight were 0.13 and 0.06kg for the Yankasa rams and Maradi bucks respectively (Table 3.1.1). The Yankasa rams consumed more feed and water and gained more weight than the Maradi bucks. The Yankasa rams under heat stress of the hot dry season and on food of low moisture content required 202.5ml/$kg^{0.73}$/day. Maradi buck under similar conditions required 152.4ml/$kg^{0.73}$/day. The Yankasa rams consumed more feed and had higher faecal output compared with the Maradi bucks. Faecal water output of the rams and bucks were 16.08ml/$kg^{0.73}$/day and 9.82ml/$kg^{0.73}$/day respectively. (Table 3.1.2). Water loss in urine by the Yankasa ram was 45.6ml/$kg^{0.73}$/day while the Maradi buck lost 42.0ml/$kg^{0.73}$/day. Evaporated water loss from ram was 162.4ml/$kg^{0.73}$/day while the Maradi buck lost 120.4ml/$kg^{0.73}$/day.

Serum sodium for the Yankasa rams and Maradi bucks were 138.05 and 137.90meq/litre respectively. Urinary sodium averaged 34.3 and 31.4meq/l for the Yankasa rams and Maradi bucks respectively (Table 3.1.3).

Data on the water balance status of each animal are shown in table 3.1.4.

The results of the present study showed that Maradi goats can tolerate heat stress better than Yankasa sheep. The Maradi goats drank less water, and produced drier

Table 3.1.1: Growth performance of Yankasa rams and Maradi bucks used in water balance trial.

	SPECIES		
	SHEEP	GOATS	SE[1]
Number of animals	4	4	
Initial weight (kg)	25.63	19.83	0.24
Final weight (kg)	27.50	20.70	0.27
Weight gains (kg)	1.88	0.87	0.09
Average daily gain (kg)	0.13[b]	0.06[a]	0.007

[1] Standard error

[ab] Means within the same variable bearing different superscript differ ($P < 0.01$).

Table 3.1.2: Water balance of Yankasa rams and Maradi goats.

	SPECIES		
	SHEEP	GOATS	SE[1]
No. of animals	4	4	
Average of liveweight (kg)	25.56	20.16	0.25
Metabolic mass ($kg^{0.73}$)	10.95	8.96	0.08
Water drunk ml/$kg^{0.73}$/day	202.5[b]	152.4[a]	8.14
Water intake in food ml/$kg^{0.73}$/day	3.17	2.75	0.03
Metabolic water ml/$kg^{0.73}$/day	19.02[b]	10.95[a]	0.36
Water loss in faeces ml/$kg^{0.73}$/day	16.08[b]	9.82[a]	0.84
Water loss in urine ml/$kg^{0.73}$/day	45.60	42.00	2.07
Evaporated water loss ml/$kg^{0.73}$/day	162.40[b]	120.40[a]	6.74
Average daily faecal output (gm)	302.10	208.80	10.92
Average daily urine production (ml)	501.1	382.9	9.16
Daily water intake (ml)	2210.00	1364.00	68.79
Daily Hay intake (gm)	500.00	375.00	

[1] Standard error

[a,b] Means within the same variable bearing different superscript differ ($P < 0.01$)

faeces than Yankasa sheep. Evaporative water loss was 162.4ml/$kg^{0.73}$/day and 120.4ml/$kg^{0.73}$/day for the Yankasa sheep, Maradi goats respectively. The percentage faecal water ranged from 50-60% for Yankasa sheep and 40-45% for Maradi goats.

Table 3.1.3: Sodium and potassium levels in serum and urine of sheep and goats (meq/litre)

	SPECIES		
	SHEEP	GOATS	SE[1]
No. of animals	4	4	
Serum Na^+ meq/litre	138.05	137.90	0.93
Serum K^+ meq/litre	3.60	3.50	0.18
Urine Na^+ meq/litre	34.30	31.40	0.43
Urine K^+ meq/litre	123.40	104.4	4.06

[1] Standard error

Table 3.1.4: Water balance of Yankasa sheep and Maradi goats when drinking water ad libitum

Animal specie	Animal Number	Average live-weight (kg)	Metabolic size $kg^{0.73}$	Water Intake ml/$kg^{0.73}$/day Drunk	In food	Metabolic Water	Water loss ml/$kg^{0.73}$/day In Urine	In faeces	Evaporated
Sheep	12	26.00	10.79	221.86	3.20	17.92	45.81	15.21	181.96
	53	27.00	11.09	188.78	3.14	18.12	33.35	17.79	152.90
	47	26.25	10.86	193.18	3.22	18.27	48.27	15.29	152.62
	13	27.00	11.09	206.37	3.15	19.79	39.43	16.52	162.26
Goats	73	20.60	9.10	145.84	2.86	16.99	40.35	11.04	113.99
	18	19.55	8.76	178.08	2.80	16.65	47.04	12.06	138.43
	19	20.00	8.91	138.77	2.67	16.68	41.30	8.28	108.24
	17	20.50	9.07	147.11	2.69	17.47	30.50	7.52	120.76

Experiment 2

3.2: BREED DIFFERENCES IN WATER METABOLISM OF PENNED INDIGENOUS SHEEP AND GOATS.

Performance of the animals

Significant differences ($P<0.01$) existed between the water intake of sheep and goats and between the various breeds of sheep and also goats (Table 3.2.1). Average daily water intake were 2207ml, ($202.48ml/kg^{0.73}$), 1757ml, ($162.84ml/kg^{0.73}$), 564ml, ($107.62ml/kg^{0.73}$) and 1046ml, ($147.32ml/kg^{0.73}$) for Ouda sheep, Yankasa sheep, Sahel and Maradi goats respectively. Mean daily weight gains obtained were 0.131kg, 0.110kg for the Ouda and Yankasa breeds of sheep respectively while the values were 0.015kg and 0.05kg for the Sahel and Maradi breeds of goats respectively. There was no significant difference ($P>0.05$) between feed intake of the two breeds of sheep but statistical significant difference ($P<0.05$) existed for feed intake between the Sahel and Maradi goats.

Blood composition

Significant differences ($P<0.01$) were found between values for plasma chloride, magnesium, potassium of sheep and goats. Differences in plasma sodium was significant at ($P<0.05$) (Table 3..2.2). The detailed values of the serum ablumin, blood urea nitrogen, packed cell volume, RBC, haemoglobin, total protein, WBC, alkaline phosphatase, are shown in Table 3.2.2.

Table 3.2.3 shows the weight of the various prime cuts of the animals in each breed. Dressing percentage was about 54% for the sheep and 55% for the goats. Significant differences ($P \leq 0.01$) existed between the prime cuts of the sheep and goats. The sheep were heavier at slaughter, and also yielded bigger meat cuts.

Composition of the whole and Empty Bodies of Sheep and Goats

The various compositions of each animal used in the study are given in Tables 3.2.4 and 3.2.5. A wide range of body composition was exhibited by the goats, for example, fat content ranged from 3.56 - 33.03% of live weight (L.W.). Body water as a percentage of liveweight ranged from 67.34-70.77 for Ouda breed of sheep, and 52.37-71.52 for Yankasa. The latter were 68.92-74.69 and 48.16-67.95 for Sahel and Maradi goats respectively.

Table 3.2.6 shows the breed averages for body composition. Total body water (as % L.W.) was 68.9, 62.2 for the Ouda and Yankasa sheep, and 71.2 and 56.6 for Sahel and Maradi goats respectively.

Table 3.2.7 shows the mean values for tritiated water space (TOH space), biological half-life of tritium and water turn-over rate for each breed, of sheep and goats. TOH space was least for Maradi goats being 66.1% of liveweight while the value for Sahel goat was 77.8%. TOH space values for Yankasa and Ouda were

Table 3.2.1: Performance of the difference breeds of sheep and goats.

SPECIES	1 SHEEP	2	3 GOATS	4	
BREEDS	OUDA	YANKASA	SAHEL	MARADI	
No. of animals	4	44	4	4	SE[1]
Initial weight (kg)	22.25	22.52	11.6	12.1	
Final weight (kg)	30.52	29.50	12.57	16.25	
Weight gain (kg)[ab]	8.27	6.97	0.98	3.15	0.27
Average daily gain (kg)	0.13	0.11	0.015	0.05	0.04
Average daily Hay intake[ac] (g)	455.2	455.9	293.3	301.1	6.41
Average daily concentrate intake (g)	333	333	200	267	
Average daily water intake[ab] (ml)	2207	1739	664	1046	34.1
Average daily water intake ml/kg$^{0.73}$	202.48	162.84	107.62	147.32	

[a] 1,2 Vs 3,4 sig at P/0.01

[b] 1 Vs 2, sig at P/0.01 and 3 Vs 4 sig at P/0.01

[c] 1 Vs 2 not sig P > 0.05 but 3 Vs 4 sig at P/0.01

[1] Standard error.

Table 3.2.2: Effect of breed on blood parameters in penned sheep and goats.

SPECIES	SHEEP		GOATS		
BREEDS	OUDA	YANKASA	SAHEL	MARADI	
Groups	1	2	3	4	
No. of animals	4	4	4	4	
No. of observations	12	12	12	12	SE[1]
Plasma chloride (meg/l)[ab]	107.82	102.40	117.33	113.99	0.68
Plasma magnesium (meq/100ml)[ab]	2.53	2.81	2.27	2.48	0.039
Plasma sodium (meq/l)[c]	141.54	143.73	144.93	140.73	0.78
Plasma potassium (meq/l)[a]	3.39	3.32	4.12	3.99	0.07
Serum albumin(g/dl)[ab]	3.16	2.90	3.52	3.01	0.07
Blood urea nitrogen (mg/dl)[ad]	10.70	10.30	16.17	14.98	0.20
Packed cell volume %	26.50	29.09	26.45	29.49	0.31
MCV (femtolitres)[ab]	36.25	39.65	33.04	37.02	0.82
MCHC (g/dl)[d]	28.57	27.51	28.68	26.18	0.63
MCH (picogram)[a]	10.44	10.86	9.44	9.67	0.21
RBC[a]	7.32	7.42	8.01	7.98	0.15
Hb[e] (g/dl)	7.56	8.00	7.54	7.72	0.11
Total protein (g/dl)[f]	7.15	6.98	6.83	6.68	0.16
WBC	7700	8050	7583	7742	190.42
Alkaline phosphatase[fg] (A.U./l)	73.9	55.3	73.4	64.8	3.07

[1] Standard error

[a] 1,2 Vs 3,4 sig at P/0.01

[b] 1 Vs 2 sig at P/0.01 and 3 Vs 4 sig at P/0.01

[c] 1 Vs 2 sig at P/ 0.05 and 3 Vs 4 sig at P/0.01

[d] 1 Vs 2 not sig P/ 0.05 and 3 Vs 4 sig at P/0.01

[e] 1 Vs 2 sig at P/0.01 and 3 Vs 4 not sig P/ 0.05

[f] 1,2 Vs 3,4 sig at P/0.05

[g] 1 Vs 2 sig at P/0.01 and 3 Vs 4 sig at P/0.05

73.6 and 80.5% liveweight (L.W.) respectively. The biological half-life of tritium was least in Yankasa (115.5h) and longest in Sahel (173.3h). Water turnover per day/animal (litres) was 2.52, 2.63, 0.86, 1.09 for Ouda, Yankasa, Sahel and Maradi breeds respectively. Various relationship among factors determined in the body composition of these animals by direct slaughter technique and TOH space were examined.

1. The regression of total body water (kg) on TOH space (kg) gave the following equation,

$Y = 0.353 + 0.841\ X$

where X is the corrected TOH space (kg), Y is the total body water (kg). The correlation coefficient obtained between the total body water and corrected TOH space ($r = 0.992$) was highly significant ($P < 0.01$).

2. The regression of total body fat (kg) on corrected TOH space (kg) with live weight as a covariate gave the following multiple regression equation,

$Y_1 = -2.172 - 0.905\ X_1 + 0.949\ X_2$

where X_1 is the corrected TOH space (kg)

X_2 is the liveweight (kg)

Y_1 is the body fat (kg)

The multiple correlation coefficient between the body fat, TOH space and live weight ($r = 0.969$) was significant ($P < 0.01$).

Table 3.2.3: Mean carcass weight and weight of various prime (whole sale) cuts.

SPECIES	SHEEP		GOATS		
BREED	1 OUDA	2 YANKASA	3 SAHEL	4 MARADI	SE[1]
Liveweight (kg)[a]	30.52	29.50	12.58	16.25	1.15
Dressing percentage	54.09	54.27	55.00	55.07	0.25
Carcass wt (kg)[ab]	16.51	16.01	6.92	8.95	0,60
Leg wt (kg)[a]	5.94	5.90	2.48	3.09	0.29
Neck (kg)[ab]	1.24	1.44	0.42	0.67	0.07
Loin wt (kg)[a]	1.18	1.09	0.48	0.68	0.05
Flank wt (kg)[ab]	0.83	0.86	0.44	0.56	0.05
Shoulder wt (kg)[ab]	4.94	4.75	2.20	3.02	0.22
Ribs wt (kg)[a]	1.74	1.76	0.76	0.92	0.06
Bones wt (kg)[a]	5.18	4.88	2.39	2.49	0.16
Lean meat (kg)[ab]	11.29	11.05	4.54	6.42	0.51

[1] Standard error

[a] 1,2 Vs 3,4 sig at P$\leq$0.01

[b] 1 Vs 2 not sig P$>$0.05 and 3 Vs 4 sig at P$\leq$0.05

Table 3.2.4: Composition of the whole bodies of sheep and goats*

Breed	Animal Number	Liveweight (kg)	Water	Protein	Ash	Fat	Dry solids in gut
Ouda	1	28.0	69.14	12.70	2.72	16.78	1.4
	24	28.1	67.34	12.82	3.24	16.07	1.0
	14	31.0	70.77	13.70	4.03	12.86	0.8
	22	35.0	68.39	13.17	2.62	16.33	1.5
Yankasa	105	28.0	52.37	13.53	3.96	28.55	1.0
	91	33.0	58.61	11.29	3.08	26.00	0.9
	50	28.0	71.51	16.60	3.24	11.31	1.2
	119	29.0	71.45	13.77	3.46	13.54	1.4
Sahel	13	11.5	68.92	17.47	3.35	7.09	1.0
	12	12.8	71.85	15.25	3.23	5.82	0.9
	10	12.0	69.42	16.48	2.70	10.30	0.8
	11	14.0	74.69	16.86	2.92	3.56	1.1
Maradi	640	15.0	67.95	16.00	2.84	11.53	1.0
	63	15.0	48.16	14.96	3.04	23.08	0.8
	48	16.0	60.71	13.62	2.67	19.56	1.2
	113	19.0	49.42	13.98	3.61	33.03	1.0

*Values are expressed as percentage liveweight

Table 3.2.5: Composition of the empty bodies of sheep and goats*

Breed	Animal Number	Empty body weight (kg)	Water	Protein	Ash	Fat
Cuda	1	22.52	60.72	15.87	3.4	20.97
	24	23.27	62.15	15.44	3.9	19.36
	14	26.16	63.68	16.31	4.8	15.31
	22	28.84	60.65	16.06	3.2	19.91
Yankasa	105	24.64	47.65	15.38	4.5	32.44
	91	26.89	45.85	13.94	3.8	36.79
	50	25.27	66.42	18.44	3.6	12.57
	119	26.56	66.15	15.13	3.8	14.88
Sahel	13	9.91	66.56	20.31	3.9	8.24
	12	9.82	68.43	19.81	4.2	7.56
	10	10.78	67.15	18.31	3.0	11.53
	11	11.32	70.18	20.81	3.6	4.40
Maradi	640	12.19	63.45	19.75	3.5	14.24
	63	11.42	42.95	19.69	4.0	30.37
	48	13.02	55.96	16.81	3.3	23.90
	113	16.38	44.15	16.25	4.2	36.41

*Values are expressed p as percentage empty body weight.

3. The regression of body protein (kg) on TOH space with live weight as a covariate gave the following multiple regression equation,

$$Y_2 = 0.718 + 0.091\ X_1 + 0.039\ X_2$$

where X_1 is the corrected TOH space (kg)

X_2 is the live weight (kg)

Y_2 is the body protein (kg)

The multiple correlation coefficient obtained between body protein, TOH space and live weight ($r = 0.965$) was highly significant ($P < 0.01$).

There was a significant linear relationship between the corrected TOH space (kg) and fat-free empty body (kg).

4. The regression of the fat-free empty body (FFEB) on TOH space gave the following equation:

$$Y_3 = 1.376 + 0.808\ X_1$$

where X_1 is the corrected TOH space (kg)

Y_3 is the FFEB (kg)

The correlation coefficient between FFEB and TOH space ($r = 0.975$) was highly significant ($P < 0.01$).

5. The regression of body ash (kg) on the corrected TOH space (kg) gave the following equation:

$$Y_4 = 0.63 + 0.038\ X_1$$

where X_1 is the corrected TOH space (kg)

Y_4 is the body ash (kg)

The correlation coefficient between body ash and TOH space ($r = 0.868$) was significant ($P < 0.01$).

Table 3.2.6: Body composition of sheep and goats

Breed	1S Ouda	2S Yankasa	3G Sahel	4G Maradi	SE[1]
Liveweight (kg)	30.52	29.50	12.58	16.25	1.156
Water (% LW)[a]	68.9	62.2	71.2	55.6	3.659
Protein (% LW)[b]	13.10	13.80	16.47	14.64	0.659
Ash (% LW)	3.15	3.44	3.05	3.04	0.226
Fat (% LW)[a]	15.5	20.8	6.8	21.8	3.429
Empty body wt (kg)[b]	25.2	25.84	10.46	13.25	0.963
Water (% EBW)[a]	61.8	56.5	68.1	51.6	3.794
Protein (% EBW)[b]	15.92	15.72	19.81	18.13	0.727
Ash (% EBW)	3.83	3.92	3.67	3.17	0.263
Fat (% EBW)	18.9	24.2	7.9	26.7	4.113

[1] Standard error

% LW = Per cent live weight

% EBW = Per cent empty body weight

1S = Ouda sheep
2S = Yankasa sheep
3G = Sahel goat
4G = Maradi goat

[a] 3G Vs 4G sig at P/0.05

[b] S Vs G sig at P/0.05

Table 3.2.7: Tritiated water space, Biological half-life of tritium and water turnover rate of sheep and goats.

Breeds	Body weight (kg)	TOH space (% Liveweight)	Biological half-life	Water turnover (ltr/animal)	per 24h. ($ml/_{kg}0.73$)
Ouda	30.52	80.5±1.2	138.6+_6.5	2.52±0.35	207.92±20.2
Yankasa	29.50	73.6+_0.8	115.5+_2.4	2.63±0.22	222.33±12.4
Sahel	12.58	77.8±0.4	173.3+_12.6	0.86±0.1	135.43+_9.5
Maradi	16.25	66.1±2.8	138.6±15.4	1.09+_0.15	142.39±10.9

± Standard deviation

Fig. 1 : Equilibration curves for tritiated water injected into sheep.

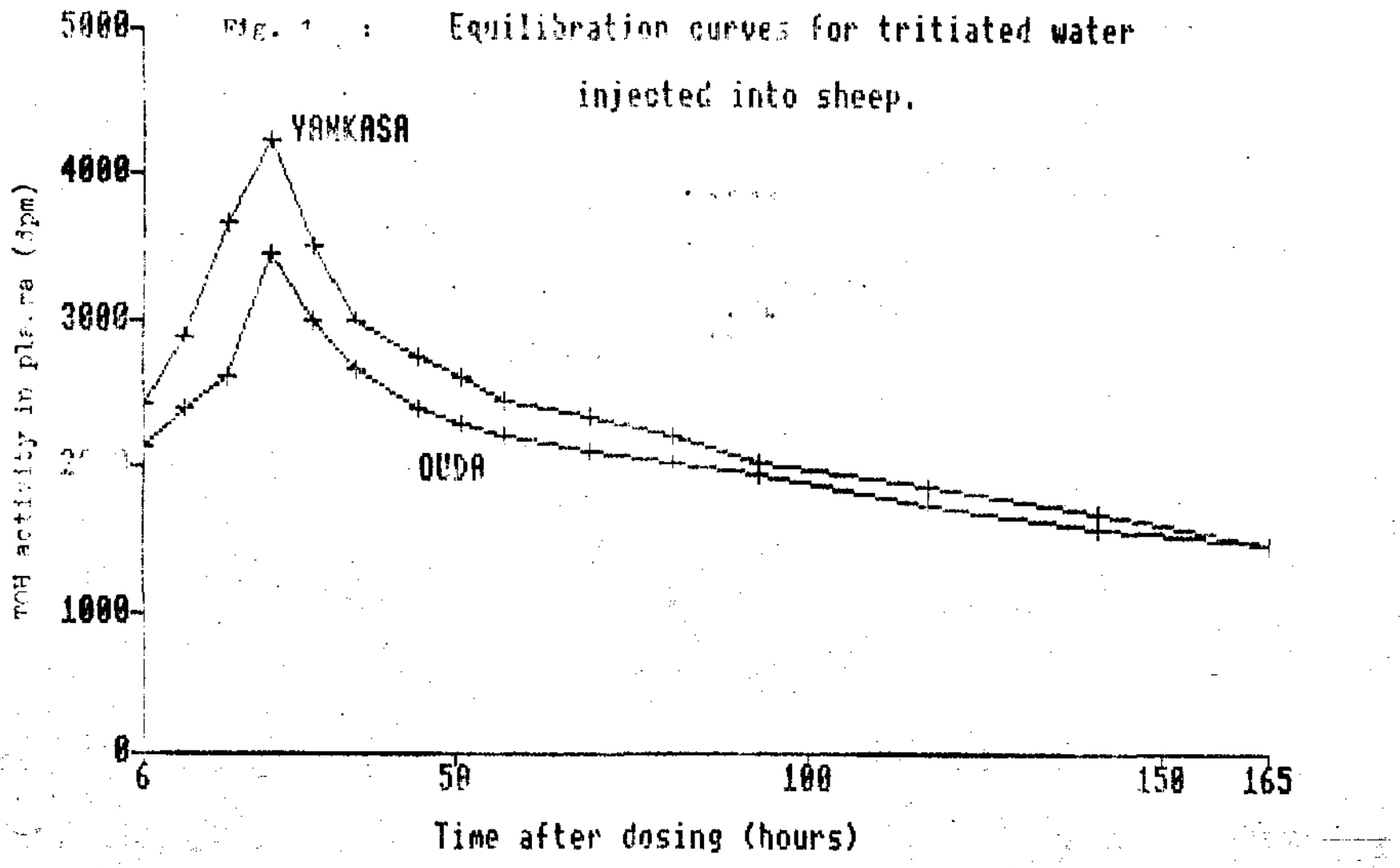


Fig. 2 : Equilibration curves for tritiated water injected into goats

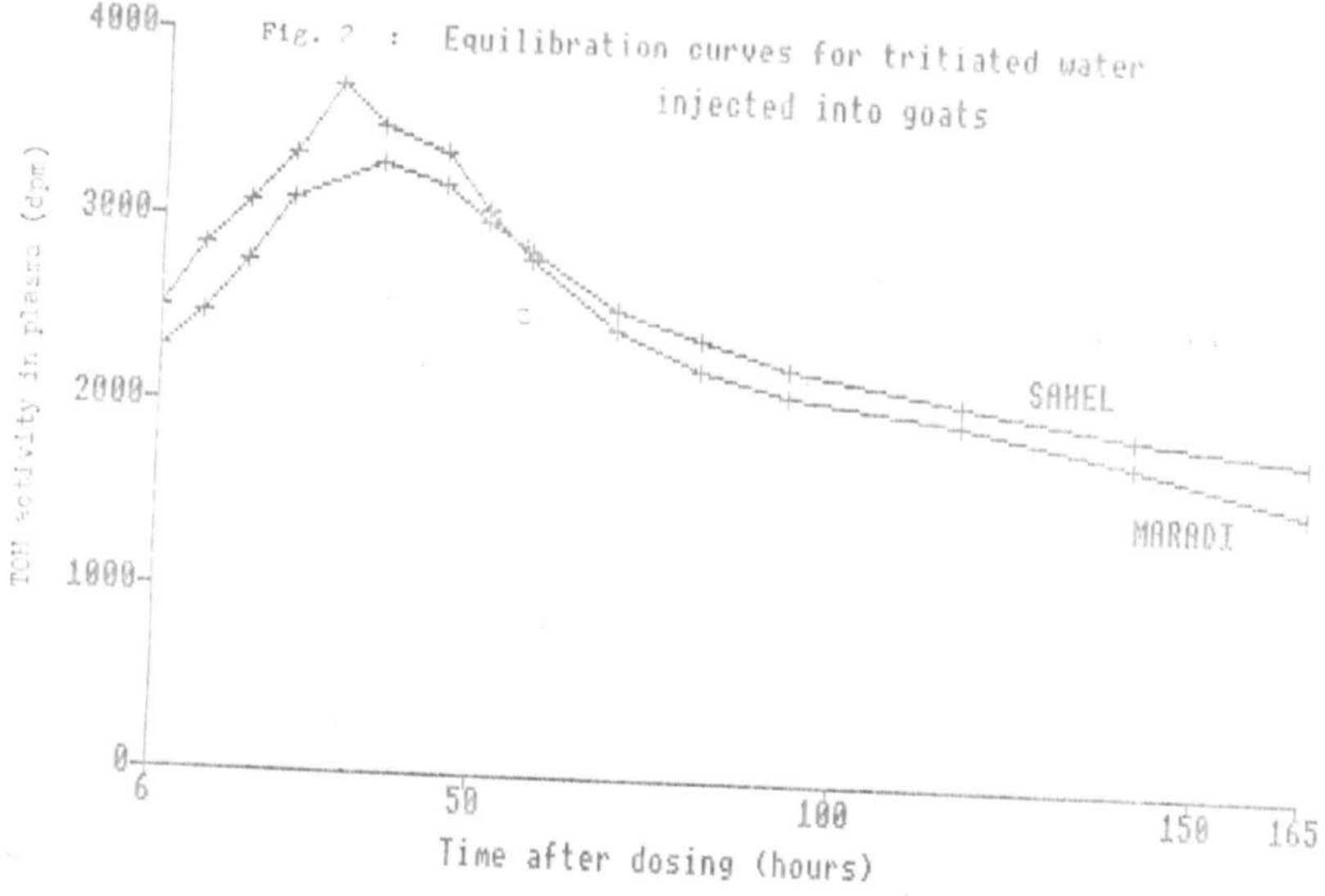
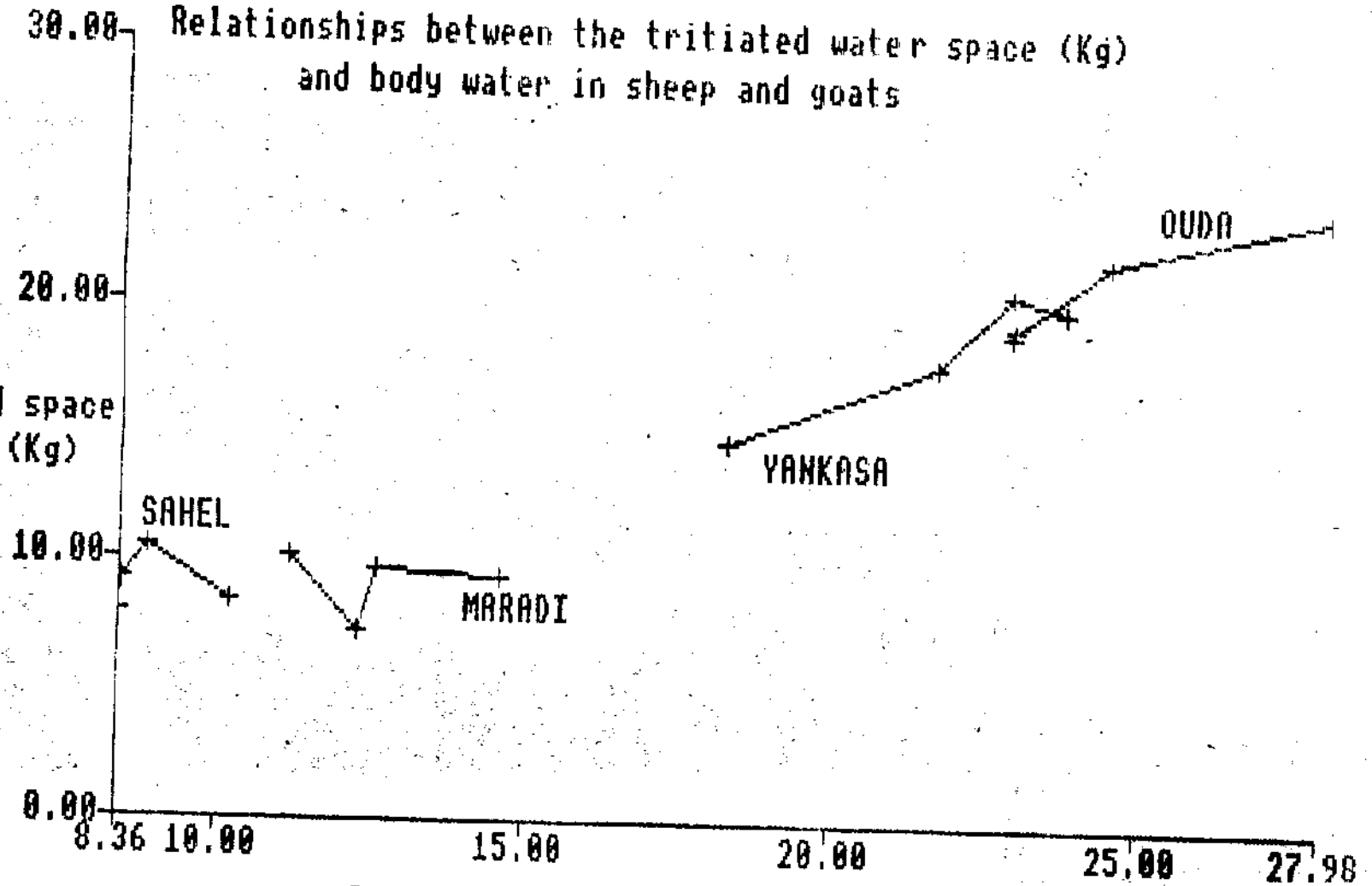


Fig. 3:

Relationships between the tritiated water space (Kg) and body water in sheep and goats



6. The relationship between corrected TOH space (X) expressed as a percentage of liveweight and total body water (Y) expressed as a percentage of live weight was as follows:

$$Y = -13.009 + 1.044X$$

The correlation coefficient obtained between the total body water and the corrected TOH space ($r = 0.921$) was highly significant ($P < 0.01$).

7. The regression of total body fat (per cent live weight) on the corrected TOH space (per cent live weight) gave the equation:

$$Y = 78.272 - 0.835X$$

where Y is the total body fat (per cent live weight) and X is the corrected TOH space (per cent live weight) The correlation coefficient ($r = 0.749$) was significant ($P < 0.01$). The regression equations (table 3.2.8) have high correlation coefficients. The upper limit for total body water was 74.69% of liveweight in Sahel goats. Total body water was inversely related to body fat as evident in the data for the goats. The water turnover of goats was the lowest.

Table 3.2.8: Regression of Tritiated water space (TOH space) on Body composition of sheep and goats.

Prediction Equations	R	R^2	SE[1]
$Y = 0.353 + 0.841X_1$	0.992	0.985	0.027
$Y_1 = -2.173-0.905X_1{}^a+0.349X_2$	0.969	0.94	0.08
$Y_2 = 0.718+0.091X_1+0.039X_2$	0.966	0.934	0.031
$Y_3 = 1.376+0.808X_1$	0.975	0.951	0.048
$Y_4 = 0.63 + 0.038X_1$	0.868	0.754	0.005

[1] Standard error

X_1 TOH space

X_2 Liveweight (kg)

Y = total body water (kg)

Y_1 = body fat (kg)

Y_2 = body protein (kg)

Y_3 = fat free empty body (FFEB) (kg)

Y_4 = body ash (kg)

Experiment 3

3.3: EFFECT OF AGE AND SEX ON THE WATER REQUIREMENT OF PENNED SHEEP AND GOATS.

There was a significant difference ($P \leq 0.01$) between age with regards to water intake (Table 3.3.1). The average daily intakes of water per goat were 396.9, (64.21ml/$kg^{0.73}$), 805.2, (93.63ml/$kg^{0.73}$), 476.2, (77.68ml/$kg^{0.73}$) and 9 877.7ml (101.48ml/$kg^{0.73}$) for treatments 1, 2, 3 and 4 respectively; while for sheep the values were 1038.7, (105.99ml/$kg^{0.73}$), 1613.4, (124.49ml/$kg^{0.73}$), 1130.5, (117.52ml/$kg^{0.73}$) and 1826.8ml, (149.74ml/$kg^{0.73}$) for treatments 5, 6, 7 and 8 respectively. There was significant difference ($P \leq 0.01$) between water intake of sheep and goats (treatments 1, 2, 3, 4 Vs 5, 6, 7, 8). Significant differences ($P \leq 0.01$) were obtained between the water intake of the 1 year old and 2 years old (trt 1, 3, 5, 7, Vs 2, 4, 6, 8) (396.9, 476.2, 1038.7, 1130.5, Vs 805.2, 877.77, 1613.4, 1826.8ml) (64.12, 77.68, 105.99, 117.52 Vs 93.63, 101.48, 124.49, 149.74ml/$kg^{0.73}$). Significant difference ($P \leq 0.05$) existed between the water intake of the male sheep and female sheep (5, 6 Vs 7, 8). The female goats drank more free water than the male goats but the difference was not statistically significant.

A significat difference ($P \leq 0.01$) existed between the one year old and 2 years old in hay consumption. The animals in treatment 1 consumed an average of 238.0g per day while those on treatment 2 consumed 297.4g daily. Average daily hay intake for treatment 3 was 239.7g while

the 2 years old female (treatment 4) consumed 390.6g. The hay intake of the sheep were 297.8g, 428.8g, 300.8g and 428.0g for the 1 year old male, 2 years old male, 1 year old female and 2 years old female (treatments 5, 6, 7 and 8) respectively.

There was no significant difference in mean daily weight gain between sex within the same age group. Significant difference ($P < 0.01$) in average weight gain existed between sheep and goats, and between age within sex (Table 3.3.1). The 2 year old (male and female) consumed more water per metabolic size than the 1 year old sheep and goats, (Tables 3.3.1 and 3.3.2). Differences in water intake of the male and female goats were not significant ($P > 0.05$) but significant differences ($P < 0.05$) existed between water intakes of male and female sheep (Tables 3.3.1 and 3.3.3).

Table 3.3.1: Effect of age and sex on weight gain, water and feed intake of penned sheep and goats

	TREATMENTS								
	GOATS				SHEEP				
	1m	2m	3f	4f	5m	6m	7f	8f	SE[1]
No. of animals	5	5	5	5	5	5	5	5	
Initial weight (kg)	10.8	17.52	10.66	17.6	20.16	30.46	19.66	28.76	0.33
Final weight (kg)	13.5	20.62	13.3	20.82	25.46	36.46	24.76	34.44	0.32
Weight gain (kg)	2.70	3.10	2.64	3.22	5.30	5.95	5.10	5.68	0.11
Average Daily gain (kg)[abcdef]	0.05	0.06	0.05	0.06	0.11	0.12	0.10	0.11	0.002
Daily Hay intake (g)[abcdef]	238.9	297.4	239.7	300.6	297.8	428.8	300.8	428.0	2.97
Daily concentrate (g) intake	166	208	166	208	208	292	208	292	..
Water intake (ml)[adefg]	396.9	805.2	476.2	877.77	1038.7	1613.4	1130.5	1862.8	19.028
Water intake $ml/kg^{0.73}$	64.12	93.63	77.68	101.48	105.99	124.49	117.52	149.74	

[1]Standard error

m = male
f = female 1,3,5,7 - 1 year old, 2,4,6,8 - 2 years old.

[a]1,3,5,7 Vs 5,6,7,8 sig at P/0.01 [b]1,3,5,7 Vs 2,4,6,8 sig at P/0.01

[c]1,2 Vs 3,4 not sig P> 0.05 but 5,6 Vs 7,8 sig P/0.01

[e]1,3 Vs 5,7 sig at P/0.01 [f]2,4 Vs 6,8 sig at P/0.01

[g]1,2 Vs 3,4 sig at P/0.01 and 5,6 Vs 7,8 sig P/0.01

Table 3.3.2: Effect of age on water and feed intake of penned sheep and goats

	GOATS		SHEEP	
Age of animals (years)	1	2	1	2
No. of animals	10	10	10	10
Average weight (kg)	12.06	19.14	22.51	33.52
Metabolic mass $(kg)^{0.73}$	6.16	8.63	9.71	12.70
Average daily Hay intake (g)	239.3	299.0	299.3	428.4
Average daily concentrate intake (g)	166	208	208	292
Average daily water intake (ml)	436.55	341.49	1084.6	1780.1
Average water intake/$kg^{0.73}$[a]	70.87	97.51	111.70	140.80

[a] 1 Vs 2 sig at P≤0.01

Table 3.3.3: Effect of sex on water and feed intake of penned sheep and goats.

	GOATS		SHEEP	
Sex of animals	MALE	FEMALE	MALE	FEMALE
No of animals	10	10	10	10
Average weight (kg)	15.61	15.60	28.12	26.91
Metabolic mass $(kg)^{0.73}$	7.43	7.43	11.42	11.06
Average daily Hay intake (g)	268.15	270.15	363.3	364.4
Average daily concentrate intake (g)	187	187	250	250
Average daily water intake (ml)	601.05	676.99	1326.05	1546.65
Average water intake/$kg^{0.73}$	80.89	91.11	116.12	139.84[b]

[b] Male sheep Vs female sheep sig at $P \leq 0.05$

Experiment 4

3.4: SEASONAL VARIATIONS AND INFLUENCE OF INTERMITTENT WATERING ON GRAZING YANKASA SHEEP.

The season of the year had highly significant ($P<0.01$) effects on the water intake and weight gains of the Yankasa sheep. The water intake of the animals during the dry season were 1839ml, (188.85ml/$kg^{0.73}$), 1328.2ml, (146.76ml/$kg^{0.73}$), 1173.7ml, (142.79ml/$kg^{0.73}$) and 1070.1ml, (138.27ml/$kg^{0.73}$) for the 24h, 48h and 96h watering intervals respectively (treatments 1, 2, 3 and 4). The values were 272.0ml, (26.48ml/$kg^{0.73}$), 202.8ml, (20.44ml/$kg^{0.73}$), 205.1ml, (20.99ml/$kg^{0.73}$), 205.4ml (21.11mg/$kg^{0.73}$) free water intakes during the wet season (Table 3.4.1) for the same treatments.

The average daily gains were significantly lower ($P<0.01$) during the dry season than the wet season. During the hot dry season intermittent watering had a negative effect on growth rate of Yankasa sheep. The animals were losing weight except on daily watering regimen during which they gained 66g daily. The animals on 48h, 72h and96h watering intervals (Table 3.4.1) lost 18.8g, 115.2g and 172g daily. During the rainy season the animals gained weight despite the watering intervals imposed on them. Daily weight gains were 135.6g, 124.4g, 118g and 107.2g for 24h, 48h, 72h and 96h watering regimen respectively (Table 3.4.1).

Blood biochemical constituents namely PCV, total proteins, RBC, Hb were significantly ($P<0.05$) higher during wet season. Watering intervals significantly affected ($P<0.05$) the RBC, Hb, blood urea nitrogen components of blood (Table 3.4.2). Blood urea nitrogen was elevated with an increase in watering intervals.

Results in Table 3.4.3 show that significant differences ($P<0.05$) existed in plasma sodium (Na), potassium (K), Magnesium (Mg) and Chloride (Cl^-) of sheep subjected to intermittent watering intervals when the two seasons wet and dry were compared. Plasma K values for sheep on 24h, 48h, 72h and 96h watering intervals during dry season were 5.02, 5.10, 5.15 and 5.44 meq/litre while the wet season values were 3.45, 3.38, 4.04 and 3.93 meq/litre. The chloride, magnesium and sodium values in plasma were significantly higher ($P<0.01$) in the dry season than the rainy season.

Seasonal effects were prominent on the physiological parameters measured. (Table 3.4.4). Prolonged watering intervals exacted serious stress on the animals during the dry season. Variations in rectal temperature was slight (Table 3.4.4) and mean values obtained during the dry season were 39.07°C, 39.19°C and 39.38°C and 39.59°C for animals watered at 24h, 48h, 72h and 96h intervals respectively. For the wet season rectal

Table 3.4.1: Performance of grazing Yankasa sheep intermittent watering during dry and wet season

	DRY SEASON				WET SEASON				
	1	2	3	4	5	6	7	8	
Watering intervals	24h	48h	72h	96h	24h	48h	72h	96h	SE[1]
No of animals	5	5	5	5	5	5	5	5	
Initial weight (kg)	20.8	20.9	20.8	20.8	20.92	20.08	19.74	19.9	0.652
Final weight (kg)	24.1	19.96	15.04	12.2	27.7	26.3	25.64	25.25	0.692
Weight gained (kg)	3.3	-0.94	-5.76	-8.6	6.78	6.22	5.9	5.35	0.431
Average daily gain[acdefhi] (kg)	0.066	-0.0188	-0.1152	-0.172	0.1356	0.1244	0.118	0.107	0.0086
Concentrate intake (g)	250	250	250	250	250	250	250	250	
Water intake[abcdefg]	1830.0	1328.2	1173.7	1070.1	272.0	202.8	205.1	205.4	
Water intake ml/kg$^{0.73}$	188.85	146.76	142.79	138.26	26.48	20.44	20.99	21.11	22.3

[1]standard error

[a]1,2,3,4 Vs 5,6,7,8 sig at P/0.01 [b]1 Vs 2,3,4 not sig P> 0.05, [c]2 Vs 3,4 sig at P/0.01

[d]3 Vs 4 not sig P> 0.05 [e]5 Vs 6,7,8 sig at P/0.01, [f]6 Vs 7,8 sig at P/0.01

[h]1 Vs 2,3,4 sig at P/0.05 [i]7 Vs 8 sig at P/0.01

Table 3.4.2: Blood Biochemistry of grazing Yankasa sheep under intermittent watering during dry and wet seasons.

	Treatments								
	DRY SEASON				WET SEASON				
Groups	1	2	3	4	5	6	7	8	SE[1]
Watering intervals (h)	24	48	72	96	24	48	72	96	
No of animals	5	5	5	5	5	5	5	5	
No of observations	25	25	25	25	25	25	25	25	
PCV[a] (%)	27.40	28.68	32.12	33.82	30.92	30.64	32.72	31.40	0.58
MCH (picograms)	9.65	9.65	9.71	9.47	11.80	14.33	12.75	11.23	0.21
MCHC (g/dl)	33.14	33.19	32.19	30.85	39.31	39.18	39.47	37.77	0.35
MCH (femtolitres)	29.00	28.99	30.22	30.70	30.34	36.60	32.35	29.80	0.59
Total protein[a] (g/dl)	6.78	6.89	7.08	7.01	6.48	6.796	6.692	6.736	0.13
RBC[abcde]	9.45	9.88	10.62	11.01	10.28	8.404	10.173	10,641	0.19
WBC	8378	8348	8328	9908	11228	13824	10908	10624	1170.07
Hb[abef] (g/dl)	9.12	9.52	10.35	10.38	12.15	11.96	12.92	11.85	0.19
Blood urea nitrogen[hcf] (mg/dl)	9.36	11.50	13.23	14.19	-	-	-	-	0.34
Serum albumin[g] (g/dl)	3.42	3.50	3.61	3.58	-	-	-	-	0.08
Phosphetase[f] (A.U./l)	86.5	78.8	67.7	87.4	-	-	-	-	6.05

[1] Standard error

[a] 1,2,3,4 Vs 5,6,7,8 d sig at P<0.05 [b] 1 Vs 2,3,4 sig at P<0.05 [c] 2 Vs 3,4 sig at P<0.01

[d] 5 Vs 6,7,8, sig at P<0.01, [e] 6 Vs 7,8 sig at P<0.01, [f] 3 Vs 4 sig at P<0.05

[g] 1 Vs 2,3,4 not sig P>0.05 and 2 Vs 3,4 not sig P>0.05

temperatures were slightly lower being 38.73°C, 38.95°C, 38.94°C, 38.91°C for animals watered at 24h, 48h, 72h and 96h intervals respectively.

Respiratory rate was significantly ($P/0.01$) affected by watering regimen especially during the dry season. The values showed decrease with increase in watering intervals and were 32,43, 25.77, 20.53 and 19.87 for treatments 1, 2, 3 and 4 respectively. Jaw movements were drastically reduced with an increase in watering intervals (Table 3.4.3)., Pulse rate was significantly ($P/_0.01$) affected by water deprivation in the dry season.

The effects of water deprivation could be observed from behavioural patterns of the animals during the dry season. There was a reduction in feed consumption since the animals under water deprivation stayed recumbent under shady trees while those on daily watering grazed more often. Sheep on the 72h and 96h watering regimen lost about 40% of their body weight at the end of the study. The animals grew lean and staggered whenever they attempted to graze especially during the week before the study was terminated. The hair coats were rough and their hairs were raised. The mid-portion, that is the stomach area collapsed inwards and some abnormal sounds could be heard. Towards the end of the study animals on treatments 3 and 4 went off feed and their

Table 3.4.3: Plasma minerals of grazing Yankasa sheep under intermittent watering during dry and wet seasons

	DRY SEASON				WET SEASON				
	Treatments								
	1	2	3	4	5	6	7	8	SE[1]
Watering intervals	24	48	72	96	24	48	72	96	
No of animals	5	5	5	5	5	5	5	5	
No of observations	25	25	25	25	25	25	25	25	
Potasium[abedefg] (meq/l)	5.02	5.16	5.15	5.44	3.45	3.38	4.04	3.93	0.08
Magnesium[adfhijk] (mg/100ml)	2.41	2.72	2.68	2.81	2.00	2.07	1.94	2.07	0.05
Sodium[adhijk] (meq/l)	139.84	142.53	147.62	148.31	138.76	140.83	139.65	139.41	0.58
Chloride[abcdjlm] meq/l	100.56	100.88	102.96	108.19	92.53	93.41	95.82	96.89	0.68

[1]Standard error

[a]1,2,3,4 Vs 5,6,7,8 sig at P/0.01 [b]1 Vs 2,3,4 sig at P/0.01 [c]2 Vs 3,4 sig at P/0.01

[d]3 Vs 4 not sig P> 0.05 [e]5 Vs 6,7,8 sig at P/0.05, [f]6 Vs 7.8 not sig P> 0.05, [g]7 Vs 8 sig at P/0.05

[h]1 Vs 2,3,4 not sig P> 0.05, [i]2 Vs 3,4 not sig P> 0.05 [j]5 Vs 6,7,8 sig at P/0.01

[k]7 Vs 8 not sig P> 0.05, [l]6 Vs 7,8 sig at P/0.01, [m]7 Vs 8 sig at P/0.01

Table 3.4.4: Physiologic parameters of grazing Yankasa sheep under intermittent watering during dry and wet seasons.

	Treatments								
	DRY SEASON				WET SEASON				
Groups	1	2	3	4	5	6	7	8	SE[1]
Watering intervals (h)	24	48	72	96	24	48	72	96	
No of animals	5	5	5	5	5	5	5	5	
No of observations	70	70	70	70	70	70	70	70	
Rectal temp.[abdefg]	39.07	39.19	39.38	39.59	38.73	38.95	38.94	38.91	0.05
Respiratory rate[abefhij]	32.43	25.77	20.53	19.87	29.59	28.24	25.80	23.43	0.54
Jaw movement[abefghi]	69.94	54.69	43.97	34.56	50.64	44.07	38.50	32.00	1.10
Pulse rate[bhi]	79.96	55.40	57.69	52.70					0.59

[1] Standard error

[a] 1,2,3,4 Vs 5,6,7 sig at P<0.01, [b] 1 Vs 2,3,4 sig at P<0.01, [c] 2 Vs 3,4 not sig P>0.05

[d] 3 Vs 4 not sig P>0.05, [e] 5 Vs 6,7,8 sig P<0.01, [f] 6 Vs 7,8 sig at P<0.01, [g] 7 Vs 8 sig at P<0.01

[h] 2 Vs 3,4 sig at P<0.01, [i] 3 Vs 4 sig at P<0.01, [j] 7 Vs 8 not sig P>0.05

hip bones became pronounced. The hair of the animals under water deprivation pulled off easily by mere touching after the experiment had progressed for 40 days. A decrease in urine output and dry faeces were also observed. None of the animals did despite the 40% loss in weight. These animals recovered within 1½ days when they were given regular drinking water. Water was given once a day for 5 days and then ad libitum afterwards.

In the present study the dry matter content of the grazed pastures measured was on the average, 90% in the dry season and 20% during wet season. The animals drank much less free water in the wet season compared to dry season intakes.

Experiment 5

3.5: INFLUENCE OF DIET TYPE ON WATER INTAKE OF SHEEP AND GOATS.

There was a significant difference ($P \leq 0.01$) in water intake between sheep and goats (groups 1,2,3, 4 and 5,6,7,8). The water intake was 960.1ml (93.68ml/$kg^{0.73}$), 995.5ml, (96.71ml/$kg^{0.73}$), 1013ml (94.25ml/$kg^{0.73}$) and 1257.4ml (127.53ml/$kg^{0.73}$) for sheep on hay only (group 1), hay and whole maize (group 2) hay and ground maize (group 3), hay and concentrate mixture (group 4) respectively. The water intake were 575.4ml (51.34ml/$kg^{0.73}$), 404.6ml, (55.05ml/$kg^{0.73}$), 371.4ml, (50.60ml/$kg^{0.73}$) and 530.5ml (71.88ml/$kg^{0.73}$) for goats on hay only (group 5), hay + whole maize (groip 6), hay + ground maize (group 7) and hay + concentrate mixture (group 8) respectively. A significant difference ($P \leq 0.1$) in water intake existed between animals feeding on hay only and animals on the other treatments (Table 3.5.1). The sheep on treatment 4 (hay + concentrate mixture) drank 1257.4ml (127.53ml/$kg^{0.73}$) water compared to those on hay + whole maize 955.5ml; (96.71ml/$kg^{0.73}$); hay + ground maize 1013.3ml (94.25ml/$kg^{0.73}$). Goats on hay + concentrate mixture drank 530.5ml (71.88ml/$kg^{0.73}$) while those on hay + whole maize drank 404.6 (55.05ml/$kg^{0.73}$) and goats on hay + ground maize took 371.4mls (50.6ml/$kg^{0.73}$).

Table 3.5.1: Influence of diet type on water intake and weight gains of sheep and goats

	Treatments								
	SHEEP				GOATS				
	1	2	3	4	5	6	7	8	SE[1]
No of animals	4	4	4	4	4	4	4	4	
Initial weight (kg)	20.13	21.0	20.5	20.75	15.15	14.42	14.45	14.13	0.33
Final weight (kg)	22.05	25.13	24.58	25.25	16.10	16.35	16.25	16.80	0.32
Weight gain (kg)	1.925	4.125	4.075	4.5	0.975	1.929	1.80	2.675	0.074
Average daily gain (kg)[abeefgh]	0.048	0.103	0.101	0.112	0.024	0.048	0.045	0.066	0.0018
Daily hay intake (g)[abe]	538.0	373.5	377.1	389.5	368.6	197.3	200.3	206.5	5.375
Daily concentrate meal intake (g)	-	-	-	271	-	-	-	167	
Daily whole maize intake (g)	-	271	-	-	-	167	-	-	
Daily ground maize intake (g)	-	-	271	-	-	-	167		
Average dailywater intake[abcdefg] (ml)	960.1	955.5	1013.3	1257.4	575.4	404.6	371.4	530.5	18.83
Average daily water intake/kg	0.73	93.68	96.71	94.25	127.53	57.34	55.05	50.60	71.88

[1]Standard error

[a]1,2,3,4 Vs 5,6,7,8 sig at P/0.01, [b]1 Vs 2,3,4 sig at P/0.01, [c]2,3 Vs 4 sig at P/0.01

[d]2 Vs 3 sig at P/0.05, [e]5 Vs 6,7,8 sig P/0.01, [f]6, 7 Vs 8 sig at P/0.01

[g]6 Vs 7 not sig P >0.05, [h]2 Vs 5 not sig P > 0.05

Significant difference($P \leq 0.01$) existed between the average daily gains of the animals on the different diets. Daily weight gains for sheep were 0.048kg, 0.103kg, 0.101kg, 0.112kg for groups 1,2,3 and 4 respectively; while the goats had 0.024kg, 0.048kg, 0.045kg and 0.066kg for groups 5,6,7 and 8 respectively. The animals on hay only gained the least 0.048kg for sheep (group 1) and 0.024kg for goats (group 5). The animals on hay and concentrate mixture gained most 0.122kg for sheep and 0.066kg for goats. Sheep on hay + whole maize gained 0.103kg while those on hay + ground maize gained 0.101kg. Goats on hay + whole maize gained 0.048kg while those on hay + ground maize gained 0.045kg (Table 3.5.1). The hay intake of sheep in groups 2 and 3 were 373.5g and 377.1g respectively while those in group 4 consumed 389.5g. Goats in group 6 and 7 consumed 197.3g and 200.3g respectively while those in group 8 consumed 206.5g daily.

Experiment 6

3.6: RESPONSE OF YANKASA EWES UNDER VARIOUS PHYSIOLOGIC STATES TO WATER DEPRIVATION

Water intake and performance

Significant differences ($P<0.01$) were observed between the water intake of the ewes under the different watering intervals. Water intake was 1656ml, (117.7ml/$kg^{0.73}$), 1117ml, (113.06ml/$kg^{0.73}$), 2201ml, (187.96ml/$kg^{0.73}$), 1220ml, (95.98ml/$kg^{0.73}$), 889ml, (90.81ml/$kg^{0.73}$), 1727ml (152.02ml/$kg^{0.73}$), 1212ml, (88.86ml/$kg^{0.73}$), 740ml (76.76ml/$kg^{0.73}$) and 1264ml (112.06ml/$kg^{0.73}$) for groups 1,2,3,4,5,6,7 and 8 animals respectively (Table 3.6.1). Under each watering interval the lactating ewes drank more water than the pregnant and non-pregnant ewes. The ewes under intermittent watering drank water in a cummulative fashion whenever they had access to it. Feed intake of the ewes dropped with water deprivation (Table 3.6.1). Growth rate of the animals decreased with increased water deprivation. The growth rate of the lactating animals was most seriously depressed with water deprivation. Lactating ewes on daily watering consumed 2201ml (187.96ml/$kg^{0.73}$) while those on 48h and 72h watering interval drank 1727ml (152.02ml/$kg^{0.73}$) and 1264ml (112.06ml/$kg^{0.73}$) respectively. The pregnant animals drank less water than the lactating. The pregnant ewes drank 1656ml (117.7ml/$kg^{0.73}$), 1220ml (95.98ml/$kg^{0.73}$) and 1212ml (88.86ml/$kg^{0.73}$) under 24h, 48h and 72h watering intervals.

Table 3.6.1: Performance of Yankasa ewes under various physiologic states during water deprivation

	Treatments									
	Daily watering(24hourly)			48 hourly watering			72 hourly watering			
Groups	1	2	3	4	5	6	7	8	9	SE[1]
No of animals	4	4	4	4	4	4	4	4	4	
Initial weight (kg)	34.00	20.00	26.38	34.87	20.13	25.75	33.82	20.50	26.25	0.50
Final weight (kg)	40.35	26.10	31.32	40.80	25.40	30.07	37.90	24.06	29.05	0.48
Weight gain (kg)	6.85	6.10	5.20	5.93	5.28	4.33	4.08	3.56	2.80	0.10
Average daily gain[bdfhinj] (kg)	0.14	0.12	0.10	0.12	0.11	0.09	0.08	0.07	0.06	0.002
Average daily hay[bdfhij] intake	506.00	401.30	519.80	481.20	378.9	490.2	437.5	354.4	473.8	3.34
Daily concentrate intake (g)	362.60	310.14	364.80	362.60	310.4	364.80	362.60	310.14	364.80	
Average daily water intake/ $kg^{0.73}$	117.70	113.06	187.96	95.98	90.81	152.02	88.86	76.76	112.06	

[1] Standard error

1,4,7 - Pregnant and non-lactating ewes 2,5,8 - non-pregnant and non-lactating ewes

3,6,9 - Lactating and non-pregnant ewes

[a] 1 Vs 2,3 not sig $P > 0.05$ [b] 2 Vs 3 sig at $P < 0.01$ [c] 4 Vs 5,6 not sig $P > 0.05$ [d] 5 Vs 6 sig $P < 0.01$

[f] 8 Vs 9 sig $P < 0.01$ [h] 1 Vs 2,3 sig at $P < 0.01$ [j] 7 Vs 8,9 sig $P < 0.01$ [g] 2,3, Vs 4,5,6,8,9 sig $P < 0.01$

Daily weight gains was highest in the pregnant ewes and least in the lactating ewes. Pregnant ewes in groups 1, 4 and 7 gained 0.137kg, 0.118kg and 0.081kg/day respectively while lactating ewes in treatments 3, 6 and 9 gained 0.104kg, 0.0865kg and 0.056kg/day respectively under 24h, 48h and 72h watering intervals. The non-pregnant ewes gained 0.122kg, 0.1011kg and 0.081kg when subjected to 24h, 48h and 72h watering intervals. With increased water deprivation the hay intake of the pregnant ewes was most depressed compared to non-pregnant and lactating ewes.

Blood composition

The serum protein fractions in the ewes' blood were affected by water deprivation. Mean albumin (g/dl) were 3.175, 3.067, 3.375 for pregnant, non-pregnant and lactating ewes respectively under daily watering; 3.375, 3.575 and 3.633 for 48h watering intervals; 3.683; 3.808 and 3.833 for 72h watering intervals. α2 - globulin and β-globulin were highest in pregnant ewes under 72h watering intervals with values of 1.75g/dl and 1.858g/dl respectively. The total serum protein increased with increased water deprivation (Table 3.6.2).

The plasma minerals increased with increased water deprivation (Table 3.6.3). Chloride content of plasma was 98.51meq/l, 103.77 meq/l and 99.08meq/l for pregnant, non-pregnant and lactating ewes respectively

Table 3.6.2: Blood parameters of Yankasa ewes under various physiologic states during water deprivation : Sera proteins

	Treatments									
	Daily watering(24hourly)			48hourly watering			72hourly watering			
Groups	1	2	3	4	5	6	7	8	9	SE[1]
No of animals	4	4	4	4	4	4	4	4	4	
No of observations	12	12	12	12	12	12	12	12	12	
Albumin (g/dl)	3.17 [abcdef]	3.07 [abcdfg]	3.33	3.37	3.57	3.63	3.68	3.81	3.83	0.09
α_1-golbulin (g/dl)	0.34 [abcdfg]	0.32	0.40	0.51	0.40	0.46	0.40	0.51	0.51	0.03
α_2-globulin (g/dl)	0.87 [abcdgm]	0.95	0.84	0.88	0.97	0.93	1.75	0.98	1.03	0.26
β-globulin (g/dl)	0.39 [fhijkl]	0.46	0.42	0.44	0.50	0.44	0.42	0.45	0.54	0.03
γ-globulin (g/dl)	1.54 [abcdef]	1.24	0.94	1.65	1.26	0.97	1.86	1.21	1.41	0.08
Total protein (g/dl)	6.31	5.99	6.02	6.87	6.66	5.47	7.34	6.97	7.35	0.14

[a]1 Vs 2,3 not sig P$>$0.05, [b]2 Vs 3 not sig P$>$0.05, [c]4 Vs 5,6 not sig P$>$0.05
[d]5 Vs 5,6 not sig P$>$0.05, [e]5 Vs 6 not sig P$>$0.05, [f]8 Vs 9 not sig P$>$0.05, [g]7 Vs 8,9 sig P$<$0.05
[h]1 Vs 2,3 sig P$<$0.01, [i]2 Vs 3 sig P$<$0.05, [j]4 Vs 5,6 sig P$<$0.01, [k]5 Vs 6 sig P$<$0.05
[l]7 Vs 8,9 sig P$<$0.01, [m]8 Vs 9 sig P$<$0.05

[1]Standard error
1,4,7 - pregnant and non-lactating ewes
2,5,8 - non-pregnant and non-lactating ewes
3,6,9 - Lactating and non-pregnant ewes.

Table 3.6.3: Blood parameters of Yankasa ewes under various physiologic states during water deprivation : Plasma minerals

	Treatments									
	Daily watering(24hourly)			48hourly watering			72hourly watering			
Groups	1	2	3	4	5	6	7	8	9	SE[1]
No of animals	4	4	4	4	4	4	4	4	4	
No of observations	12	12	12	12	12	12	12	12	12	
Chloride[defghi] (meq/l)	98.51	103.77	99.38	105.03	108.43	105.60	106.52	107.77	107.22	0.82
Sodium[abcdef] (meq/l)	141.22	142.02	143.63	144.98	143.88	146.59	146.39	147.04	145.12	0.93
Potassium[abcfjk] (meq/l)	4.84	4.82	4.81	5.16	5.12	5.10	5.99	5.06	4.89	0:09
Magnesium[bdeflm] (mg/100ml)	2.00	1.83	1.79	2.30	1.51	2.73	2.75	2:61	2.68	0.06

[a]1 Vs 2,3 not sig P>0.05, [b]2 Vs 3 not sig P>0.05, [c]4 Vs 5,6 not sig P>0.05, [d]5 Vs 6 sig at P<0.05
[e]7 Vs 8,9 not sig P>0.05, [f]8 Vs9 not sig P>0.05, [g]1 Vs 2,3 sig at P<0.01, [h]2 Vs 2 sig at P<0.01
[i]2 Vs 3 at P<0.01, [j]5 Vs 6 not sig P>0.05, [k]7 Vs 8,9 sig P<0.01, [l]Vs 2,3 sig at P<0.05
[m]4 Vs 5,6 sig at P<0.01

1;4;7 - Pregnant and non-lactating ewes
2;5;6 - non-pregnant and non-lactating ewes
3;6;9 - lactating and non-pregnant ewes

under daily (24h) watering intervals while for 48h intervals it was 105.03, 108.43 and 105.68meq/litre; and 106.52, 107.77 and 107.22 meq/l for 72h watering intervals. Plasma sodium values were highest for water deprived ewes compared to animals on daily watering. Ewes subjected to 72h watering intervals had 146.39 for pregnant, 147.04 for non-pregnant and 145.12meq/l for lactating ewes. Sodium levels were 141.22 for pregnant, 142.02 for non-pregnant and 143.63 meq/l at 24h watering intervals.

Plasma potassium values were highest in pregnant ewes being 4.838 meq/l, 5.162 meq/l and 5.989 meq/l for 24h, 48h and 72h watering intervals respectively.

Plasma magnesium values were highest for ewes watered at 72h intervals being 2.75 mg/100ml, 2.60mg/100ml and 2.683mg/100ml for pregnant, non-pregnant and lactating ewes respectively.

All the blood components were elevated with increased water deprivation in pregnant, non-pregnant and lactating ewe (Table 3.6.4) except alkaline phosphatase levels in lactating ewes.

Alkaline phosphatase was 52.7 A.U./l in lactating ewes subjected to daily watering while it was 46.0A.U./l in 48 and 72h groups of lactating ewes.

Packed cell volume, Haemoglobin and blood urea nitrogen exhibited significant differences ($P \leq 0.05$) between the ewes under 24h, 48h and 72h watering intervals. The PCV, Hb and blood urea nitrogen increased in ewes with increased water deprivation.

Table 3.6.4: Blood parameters of Yankasa ewes under various physiologic states during water deprivation : Blood Biochemistry

	Treatments									
	Daily watering		24hourly)	48hourly watering			72hourly watering			
Groups	1	2	3	4	5	6	7	8	9	SE[1]
No of animals	4	4	4	4	4	4	4	4	4	
No of observations	12	12	12	12	12	12	12	12	12	
Blood urea nitrogen[abcdef] (mg/dl) [aghijk]	11.7	9.71	10.2	13.2	10.36	11.15	11.69	12.47	11.83	0.53
Haemoglobin[a] (g/dl)	8.81	9.74	8.19	10.03	9.67	8.52	10.35	9.87	8.22	0.29
White blood cell[abcdfj]	8892	7442	6000	8842	6925	5475	10283	7633	7800	59.2
Red blood cell[cdklmn]	9.05	9.25	8.27	10.13	8.62	8.01	9.42	9.58	7.68	0.28
PCV[cgijk]	30.00	29.75	24.25	32.92	29.25	25.83	32.75	29.50	24.50	0.86
MCHC[bcdefl] (g/dl)	32.13	32.77	33.84	30.49	33.52	32.96	33.14	33.46	33.72	0.61
MCH[bdefhl] (picogram)	10.96	10.78	10.08	9.89	11.24	10.64	11.53	10.34	10.84	0.39
MCV[dflmnc] (femtolitres)	33.35	32.82	29.14	32.41	34.01	32.50	34.81	30.94	31.18	1.16
Alkaline phosphatase[delopq] (K.U./l)	36.9	55.4	52.7	51.2	58.2	46.0	61.9	69.0	46.0	6.69

[a]1 Vs 2,3 sig at P/0.05, [b]2 Vs 3 not P>0.05, [c]4 Vs 5,6 sig at P/0.01, [d]5 Vs 6 not P>0.05
[e]7 Vs 8,9 not sig P>0.05, [f]8 Vs 9 not sig P>0.05, [g]2 Vs 3 sig at P/0.01, [h]4 Vs 5,6 sig at P/0.
[i]5 Vs 6 sig at P/0.05 [j]7 Vs 8,9 sig at P/0.01, [k]8 Vs 9 sig at P/0.01, [l]1Vs 2,3 not sig P>0.05
[m]2 Vs 3 sig at P/0.05, [n]7 Vs 8,9 sig at P/0.05, [o]4 Vs 5,6 not sig P>0.05, [p]8 Vs sig at P/0.05
[q]1,2,3 Vs 4,5,6,7,8 not sig P>0.05

[1]Standard error.

Table 3.6.5: Physiologic parameters of Yankasa ewes during water deprivation

	Treatments									
	Daily watering(24hourly)			48hourly watering			7 hourly watering			
Groups	1	2	3	4	5	6	7	8	9	SE[1]
No of animals	4	4	4	4	4	4	4	4	4	
No of observations	80	80	80	80	80	80	80	80	80	
Jaw movement[abcdef]	59.87	59.29	58.21	52.29	51.06	49.43	46.25	45.68	45.49	0.83
Respiratory rate[ghijkl]	26.56	27.72	24.36	24.67	20.63	22.43	25.58	20.18	21.13	0.29
Rectal temperature[ghijkm] °C	38.99	38.66	38.79	39.15	38.86	39.08	39.46	39.00	39.00	0.03

1;4,7 - Pregnant and non-lactating ewes 2,5,8 - Non-pregnant and non-lactating ewes
3,6,9 - Lacting and non-pregnant ewes
[1]standard error
[a]1 Vs 2,3 not sig P>0.05, [b]2 Vs 3 not sig P>0.05, [c]4 Vs 5,6 not sig P>0.05
[d]5 Vs 6 not sig P>0.05, [e]7 Vs 8,9 not sig P>0.05, [f]8 Vs 9 not sig P>0.05
[g]1 Vs 2,3 sig P<0.01, [h]2 Vs 2,3 sig P<0.01, [i]4 Vs 5,6 sig P<0.01, [j]5 Vs 6 sig P<0.01
[k]7 Vs 8,9 sig P<0.01, [l]8 Vs 9 sig P<0.05, [m]8 Vs 9 sig P<0.01

Physiologic parameters

Table 3.6.5 shows the results of the different physiologic parameters measured in the study. Jaw movement was significantly affected ($P<0.05$) by water deprivation and it decreased with increased watering intervals. Respiratory rate also decreased while Rectal temperature increased with increased watering intervals. The pregnant ewes had the highest rectal temperature followed by the lactating ewes and the non-pregnant ewes which recorded the least rectal temperature at each watering regime.

Milk yield and composition

Milk production of the lactating ewes decreased with increased watering intervals (Table 3.6.6). The percentage milk components namely the total solids, solid not fat, fat, ash and crude protein increased as the water fraction decreased.

Reproductive performance

Table 3.6.7 shows the reproductive performance of the pregnant Yankasa ewes under water deprivation. Abortion rate increased with water deprivation and the only stillbirth was recorded under 72h watering intervals. Lamb mortality was highest with ewes most deprived of drinking water. Pregnant ewes subjected to 72h watering interval appeared uncomfortable, very nervous and also showed more frequent bleating. Heavier lambs were born by ewes that had daily drinking water compared to water deprived ewes. The ewes subjected to water deprivation were observed to drink in a cumulative fashion.

Table 3.6.6: Milk yield and composition of lactating Yankasa ewes under water deprivation

	Treatments			
	Daily watering 24 hourly	48hourly	72hourly	SE[1]
Group	3	6	9	
No of animals	4	4	4	
Average milk yield/ head/day[ab] (ml)	135.8	87.8	60.6	4.36
Total solids[ab] (%)	14.97	16.51	19.21	0.51
Water content (ml)	85.03	83.49	80.79	0.80
Solid not fat[cd] (%) (SNF)	10.95	11.73	13.49	0.56
Fat[ab] (%)	4.02	4.84	5.72	0.17
Ash[ab] (%)	0.72	0.79	0.90	0.02
Crude protein[ad] (CP) %	6.14	6.67	7.02	0.84

[1] Standard error

[a] 3 Vs 6,9 sig at P/0.01

[b] 6 Vs 9 sig at P/0.01

[c] 3 Vs 6,9 sig at P/0.05

[d] 6 Vs 9 not sig P 0.05

Table 3.6.7: Birth records of pregnant Yankasa ewes under water deprivation

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	Treatments		
	Daily watering (24hourly)	48hourly watering	72hourly watering
Group	1	4	7
No of ewes	4	4	4
Twinning rate, %	25	0	25
Singles, %	75	75	25
Stillbirth, %	0	0	12.5
Abortion, %	0	25	50
Males,%	60	33.33	0
Females, %	40	66.67	40
Average birth weight of singles (kg)	3.0	2.67	2.5
Average birth weight of twins (Kg)	2.5	-	2.0
Average birth weight of lambs (kg)	2.75	2.67	2.25
Mortality in the first 3 months	20	33.33	50

Experiment 7

3.7: EFFECT OF FEED RESTRICTION ON WATER REQUIREMENT OF SHEEP.

There was a highly significant ($P/0.01$) effect of feed intake on water intake of the animals in the two trials (table 3.7.1 and 3.7.2). In trial 1 animals in treatment 1 that had abundant feed supply took 1123ml (116.13ml/$kg^{0.73}$) while those animals on 72hourly feeding drank averagely 573ml (64.23ml/$kg^{0.73}$). In trial 2 animals in treatment 1 on full feed drank 1117ml (112.94ml/$kg^{0.73}$) while those in treatment 3 on a quarter feed drank 682ml (72.25ml/$kg^{0.73}$). The feed intake of the animals significantly ($P/0.01$) affected their average daily weight gain. In trial 1 animals on treatment 1 gained 0.115kg per day while those on treatment 3 gained 0.031kg. In trial 2 animals on treatment 1 (full feed) gained 0.124kg while those on treatment 3gained 0.044kg. The plasma sodium for animals in treatment 1 (trial 1) was 148.1meq/litre, treatment 2, 146.11 and treatment 3 144.70 and were significantly ($P/0.05$) different (table 3.7.3). The latter were true for trial 2 (table 3.7.4). Significant differences ($P/0.05$) existed between the plasma potassium, magnesium and sodium (meq/l) of sheep on adequate feeding and that of those sheep that were inadequately fed (table 3.7.3 and table 3.7.4). The plane of feeding (full, ½ or ¼) significantly ($P/0.05$) affected the blood urea nitrogen

Table 3.7.1: Performance of sheep on feed deprivation (Trial 1)

	Treatments 1	2	3	SE[1]
No of animals	4	4	4	
Initial weight (kg)	19.50	19.13	19.25	0.53
Final weight (kg)[b]	25.27	22.48	20.80	0.52
Weight gain (kg)[c]	5.77	3.35	1.55	0.09
Average Daily gain (kg)[b]	0.12	0.07	0.03	0.002
Hay intake (g)[c]	448.55	246.10	168.75	0.74
Concentrate intake (g)	333.00	166.50	113.22	
Water intake (ml)[c]	1123.00	865.00	573.00	28.16
Water intake ml/kg$^{0.73}$	116.13	94.32	64.23	

[1] Standard error

[a] 1 Vs 2,3 sig at P$\leq$0.05 but 2 Vs 3 not sig P$>$0.05

[b] 1 Vs 2,3 sig at P$\leq$0.01 but 2 Vs 3 sig at P$\leq$0.05

[c] 1 Vs 2,3 sig at P$\leq$0.01 and 2 Vs 3 sig at P$\leq$0.01

Table 3.7.2: Performance of sheep on partial feed restriction (Trial 2)

	Treatments			
	1	2	3	SE[1]
No. of animals	4	4	4	
Initial weight (kg)	20.63	20.38	20.63	0.47
Final weight (kg)[b]	25.57	23.90	21.87	0.46
Weight gain (kg)[c]	4.95	3.40	1.70	0.09
Average daily gain (kg)[c]	0.124	0.08	0.06	0.002
Average daily hay intake (g)[d]	430	190	125	32.20
Average concentrate intake (g)	333	167	183	
Average daily water intake (ml)[d]	1117	691	682	23.12
Water Average daily water intake ml/kg$^{0.73}$	112.94	72.05	72.25	

[1] Standard error

[b] 1 Vs 2,3 sig at P/0.01 but 2 Vs 3 sig at P/0.05

[c] 1 Vs 2,3 sig at P/0.01 and 2 Vs 3 sig at P/0.01

[d] 1 Vs 2,3 sig at P/0.01 but 2 Vs 3 not sig P > 0.05

Table 3.7.3: Blood parameters of sheep on feed deprivation (Trial 1)

	Treatments			
	1	2	3	SE[1]
No of animals	4	4	4	
Serum albumin (g/dl)[c]	3.23	2.97	2.64	0.04
Blood urea nitrogen (mg/dl)[d]	10.99	8.67	9.56	0.32
Plasma sodium (meq/litre litre)[b]	148.10	146.11	144.70	0.45
Plasma potassium (meq/l)[c]	4.80	4.76	4.61	0.03
Plasma magnesium (mg/dl)[a]	2.83	2.89	2.86	0.02
Plasma chloride (meq/l)[e]	107.51	106.52	108.18	0.44
Total protein(g/dl)[c]	6.33	5.70	5.17	0.06
MCV (femtoliters)[c]	31.31	29.55	26.16	0.60
Hb (g/dl)[c]	10.68	9.08	7.63	0.14
MCH (picograms)[c]	10.14	9.70	8.63	0.20
PCV[c]	33.00	27.75	23.00	0.50
WBC[c]	10369	10181	9156	184.47
RBC[c]	10.56	9.36	8.83	0.13
MCHC (g/dl)	32.41	32.88	32.18	0.29
Alkaline phosphtase (A.U./l)[d]	68.2	44.4	41.0	4.03

[1]Standard error

[a]1 Vs 2,3 sig at P/0.05 but 2 Vs 3 not sig P> 0.05

[b]1 Vs 2,3 sig at P/0.01 but 2 vs 3 sig at P/0.05

[c]1 Vs 2,3 sig at P/0.01 and 2 Vs 3 sig at P/0.01

[d]1 Vs 2,3 sig at P/0.01 but 2 Vs 3 not sig P 0.05

[e]1 Vs 2,3 not sig P> 0.05 but 2 Vs 3 sig at P/0.05

Table 3.7.4: Blood pafameters of sheep on partial restriction (Trial 2)

	Treatments			
	1	2	3	SE[1]
No of animals	4	4	4	
Serum albumin (g/dl)[d]	3.67	3.09	3.07	0.05
Blood urea nitrogen (mg/dl)[c]	10.64	10.03	9.19	0.11
Plasma sodium (meq/l)c	146.53	145.52	142.32	0.59
Plasma potassium (meq/l)[b]	4.88	4.65	4.47	0.03
Plasma magnesium (mg/dl)[e]	2.87	2.88	2.84	0.01
Plasma chloride (meq/l)	106.18	106.74	106.97	0.44
Total protein (g/dl)[d]	6.96	5.95	5.95	0.08
RBC[d]	11.20	9.35	8.82	0.29
Hb (g/dl)[b]	10.06	3.69	9.35	0.11
MCH (picograms)[d]	9.09	10.50	10.99	0.31
MCV (fertoliters)[a]	28.12	30.50	29.79	0.74
MCHC (g/dl)[c]	31.18	34.42	36.77	0.43
PCV[c]	31.25	28.21	25.67	0.55
WBC[f]	20125	19695	17584	567.02
Alkaline phosphatase (A.U./l)[d]	81.5	30.0	38.3	4.49

[1]standard error

[a]1 Vs 2,3 sig at P/0.05 but 2 Vs 3 not sig P 0.05

[b]1 Vs 2,3 sig at P/0.01 but 2 Vs 3 sig at P/0.05

[c]1 Vs 2,3 sig at P/0.01 and 2 Vs 3 sig at P/0.01

[d]1 Vs 2,3 sig at P/0.01 but 2 Vs 3 not sig P/ 0.05

[e]1 Vs 2, 3 not sig P > 0.05 but 2 Vs 3 sig at P/ 0.05

[f]1 Vs 2,3 sig at P/0.05 and 2 Vs 3 sig P/0.05

(mg/dl) being 10.64, 10.03 and 9.19 for treatment 1, 2 and 3 respecitvely. Frequency of feeding (table 3.7.3) significantly ($P<0.01$) affected the serum albumin (g/dl) which were 3.23, 2.97 and 2.64 for treatments 1, 2 and 3 in trial 1. Serum albumin, total protein values, Haemoglobin values, packed cell volume and RBC were reduced with feed deprivation.

Feed intake significantly affected ($P<0.01$) certain physiological parameters of the animals as shown in (tables 3.7.5, 3.7.6). Animals in treatment 1 in both trials 1 and 2 had slightly higher rectal temperature of 39.53 and 39.43 respectively compared to 39.21 and 38.83 of treatment 3 in trials 1 and 2 respectively. The jaw movement rate of animals in treatment 1 in both trials (63.29 and 62.92) were significantly ($P<0.01$) higher than 44.84 and 34.83 of treatment 3 in trials 1 and 2 respectively. Pulse rate and respiratory rate of the animals were significantly ($P<0.01$) affected by the treatments imposed on them.

Table 3.7.5: Physiologic parameters of sheep on feed deprivation (Trial 1)

	Treatments			
	1	2	3	SE[1]
No of animals	4	4	4	
Pulse rate/min[c]	65.11	57.50	52.36	0.32
Respiratory rate/min[c]	24.75	22.55	20.75	0.23
Jaw movement/min[c]	63.29	53.75	44.84	0.55
Rectal temperature °c[d]	39.53	39.20	39.21	0.02

[1] Standard error

[c] 1 Vs 2,3 sig at P<0.01 and 2 Vs 3 sig at P<0.01

[d] 1 Vs 2,3 sig at P<0.01 but 2 Vs 3 not sig P 0.05

Table 3.7.6: Physiologic parameters of sheep on partial feed restriction (Trial 2)

	Treatments			
	1	2	3	SE[1]
No of animals	4	4	4	
Pulse rate/min[c]	71.47	65.89	62.24	0.32
Respiratory rate/min[d]	24.90	21.66	21.48	0.10
Jaw movement/min[c]	62.92	45.11	34.83	0.50
Rectal temperature °C[d]	39.43	39.03	38.84	0.02

[1] Standard error

[c] 1 Vs 2,3 sig at P/0.01 and 2 Vs 3 sig at P/0.01

[d] 1 Vs 2,3 sig at P/0.01 but 2 Vs 3 not sig P>0.05

Exreriment 8

3.8: EFFECT OF FEED MANAGEMENT ON WATER INTAKE OF YANKASA SHEEP AND MARADI GOATS.

Water intake of the animals varied with the ratio of concentrate to roughage in their diet. The sheep and goats in treatment 4 fed on a diet of 70:30 concentrate to roughage drank the largest quantity of water 1566.2ml being (146.92ml/$kg^{0.73}$) and 133.09 mls/$kg^{0.73}$ daily for the goats respectively.

Significant differences ($P/0.01$) existed between sheep and goats in water consumption on corresponding diet (Table 3.8.1). The total dry matter (DM) intake of the sheep on the different diets were about the same; the same was true of the goats. The DM intake of the sheep was higher than that of their goat counterpart on corresponding diets. There was a linear reduction in water intake with a reduction in concentrate ratios. Goats on 70:30 concentrate to roughage ratio had 1050.1ml (133.09ml/$kg^{0.73}$) of water daily compared to 611.5ml (79.11ml/$kg^{0.73}$) of goats on 30:70 concentrate to roughage.

The daily weight gains of the animals were significantly ($P/0.01$) affected by their rations. Sheep on diet consisting of 70:30 concentrate to roughage had the highest average daily gain (ADG) of 0.15kg while those on 30:70 ratio had ADG of 0.09kg. Goats on 70:30 concentrate to roughage ratio in their diet had the highest ADG of 0.07kg while those on 30:70 had ADG of 0.04kg..

Table 3.6.1: Effect of concentrate to roughage ratio on water consumption and weight gains of sheep and goats.

	Treatments								
	SHEEP				GOATS				
Groups	1	2	3	4	5	6	7	8	SE[1]
Concentrate to roughage ratio	40:60	60:40	30:70	70:30	40:60	60:40	30:70	70:30	
No of animals	4	4	4	4	4	4	4	4	
Initial weight (kg)	21.50	21.25	21.00	21.75	15.33	14.95	15.42	15.13	0.98
Final weight (kg)	27.20	27.83	25.68	29.45	17.92	18.05	17.52	18.73	0.90
Weight gained (kg)	5.70	6.57	4.67	7.70	2.60	3.10	2.10	3.60	0.13
Average daily gain[abefg] (kg)	0.11	0.13	0.09	0.15	0.05	0.06	0.04	0.07	0.003
Average daily hay intake (g)	381.3	225.0	455.7	175.5	220.9	147.0	255.3	112.0	2.96
Concentrate intake (g)	276.9	414.6	207.7	483.8	152.26	243.38	181.92	284.4	-
Daily water intake intake[abcde] (ml)	1327.8	1464.5	1055.9	1566.2	749.2	846.1	611.5	1050.1	26.42
Daily water intake ml/kg$^{0.73}$	129.16	141.63	105.91	146.92	96.30	109.31	73.11	133.09	

[1]Standard error

[a]1,2,3,4 Vs 5,6,7,8 sig at P/0.01, [b]1 Vs 2 sig at P/0.01, [c]3 Vs 4 sig at P/0.05

[d]5 Vs 6 sig at P/0.01, [e]7 Vs 8 sig at P/0.01, [f]3 Vs 4 sig at P/0.01, [g]5 Vs 6 sig at P/0.05.

Table 3.8.2: Effect of feed processing on the performance of Yankasa sheep.

	Treatments				
	1	2	3	4	SE[1]
No of animals	4	4	4	4	
Initial weight (kg)	20.75	20.25	20.00	20.30	0.45
Final weight (kg)[bc]	26.23	26.80	24148	25.57	0.39
Weight gained (kg)[d]	5.35	6.55	4.60	5.20	0.19
Average Daily gain (kg)[d]	0.11	0.13	0.09	0.10	0.004
Average daily hay intake (g)[d]	354.4	381.0	327.1	361.2	5.01
Concentrate intake (g)	260	260	260	260	
Daily water intake (ml)[b]	1408	1236	1182	1253	30.42
Daily water intake ml/kg$^{0.73}$	140.52	123.23	122.74	127.08	

[1]Standard error

[a]1,2 Vs 3,4 sig at P/0.05

[b]1,2 Vs 3,4 sig at P/0.01

[c]1,3 Vs 2,4 sig at P/0.05

[d]1,2 Vs 3,4 sig at P/0.01 and 1,3 Vs 2,4 sig at P/0.01

There was a significant differences (P/0.01) in water intake of sheep fed on milled and unmilled concentrate (Table 3.8.2). Significant differences (P/0.01) existed in average daily gain between sheep on milled concentrate versus unmilled and chopped hay versus long hay. Sheep on milled concentrate and chopped hay had the highest weight gain (ADG) of 0.13kg per day and consumed more feed than the other groups (Table 3.8.2).

CHAPTER IV

DISCUSSION

DISCUSSION

Activities of all living organism are intimately associated with water. Water supplies the matrix and participates significantly in all living processes. There is considerable variation in total body water content among different species, ages, sexes, nutritional states, and various other conditions (Houpt, 1977). Leitch and Thomson (1944) reported that loss of water from the body is continuous, and that over a period of time a deficit in body water develops which is corrected periodically by the intake of water. The latter workers noted that several mechanism control the amount of water intake so that it equals the body water deficit. Water deprivation causes both the sensation of thirst and an associated behavioural drive to drink water. Andersson and McCann (1955) have shown that the centre controlling thirst and drinking behaviour is located in the medial hypothalamus.

The bulk of water obtained by the animal is usually as drinking water, under certain circumstances much water may be obtained in food. Most feedstuffs contain at least a small amount of water, and lush, green vegetation may contain 75 to 90 percent water. Non-lactating ruminants on succulent pasture may ingest little drinking water (Houpt, 1977). The oxidation of feedstuffs also yields some water. Houpt (1977) reported that the oxidation of each gram of carbohydrate

yields about 0.6ml. of water; the corresponding amounts for fats and protein are 1.1 and 0.4ml respectively per gram metabolized. The latter further stated that this oxidative or metabolic water comprises only 5 to 10 percent of total water intake and remains constant provided metabolic rate is constant.

Adequate supplies of water are an essential pre-requisite for any livestock production enterprise. Unless water requirements are known under all dietary, environmental and physiological conditions that will be encountered, it is possible that what may appear adequate at one time could be insufficient at another.

Water is required by ruminants (infact by all animals) for production needs (especially for meat and milk) and it is constantly needed to balance the continuous losses from the kidneys, skin and lungs. Attempts to provide basic data for water requirements of Nigerian sheep and goats and the factors that influence these requirements were the basis for the present study.

Water balance

The first trial was conducted to study the water balance of Yankasa sheep and Maradi goats. Results indicated that Yankasa rams consumed more feed and water and gained more weight than the Maradi bucks. Yankasa sheep gained 0.13kg per day while Maradi goats gained 0.077kg. The animals had adequate

nutrition and their movement was restricted in the metabolic cages. This may account for the high weight gains. This growth rate is slightly higher than what was obtained with the same breeds under pen or grazing conditions. Wilson (1976a) reported average weight gain of 82g per day in Southern Darfur sheep. Similarly Wilson (1976b) obtained weight gains of 87g per day for kids up till 3 months old and 67g per day to 6 months of age in Southern Darfur goats in the Sudan. These data confirms the findings of Gihad (1976) who noted that goats fed tropical natural grass-hay had a lower intake of water than sheep. Gihad (1976) suggested that low consumption of water was a factor in the better utilization of poor quality forages by goats.

The Yankasa rams also had significantly ($P<0.01$) more faecal output compared with the Maradi. Water intake and water loss in urine and faeces were significantly ($P<0.01$) higher in sheep than in goats. The study showed that Maradi goats can tolerate heat stress better than the Yankasa sheep. The Maradi goats drank less water, and produced drier faeces than the Yankasa sheep, which is an indication of better water conservation mechanism. The percentage faecal water ranged from 50-50% for Yankasa sheep and 40-45% for Maradi goats. This observation is similar to values of 57.1-57.6% found in Cheviot cross-bred wethers (Bailey, 1964) and 54-57% in Columbia wethers (Wallace et al. 1972). Yankasa sheep voided 501.1ml of

urine daily while Maradi goats excreted 382.9ml daily. This is in agreement with the report of Houpt (1977) who stated that if an excess of water is ingested, urinary volume will rise. The excretion of water by the kidney is controlled primarily by the antidiuretic hormone (ADH) of the posterior pituitary gland. If an animal is overhydrated, less ADH will be present in the blood, and the concentration of the urine may decrease until it approaches that of the plasma (Houpt, 1977).

Daily metabolic water intake of Yankasa sheep was 19.02ml/kg$^{0.73}$ which was significantly higher ($P<0.01$) than that of Maradi goats (16.95ml/kg$^{0.75}$) (Table 3.1.2). The metabolic water intake for the sheep was 8.46% of total intake while that of goats was 9.84% of the total water intake. This observation is in agreement with the findings of Houpt (1977) who reported 5 to 10% for oxidative water intake in ruminants.

In the present study, the sera and urinary sodium ions (Na^+) and potassium ions (K^+) were determined. Sodium is the major cation of extracellular fluid. Houpt (1977) reported that a relatively constant Na^+ of the extra-cellular fluid is attained by regulation of both intake and excretion of sodium so as to maintain a salt balance. Osmoconcentration of extracellular fluid is controlled primarily by variations of water intake and excretion. Potassium is the major cation of the

intracellular fluid, and 89% of the total body content of potassium is located within the cells (Houpt, 1977). Renal handling of potassium ions involves exchanges of K^+ with Na^+ between tubular fluid and plasma. The exchanges are influenced by Na^+ and hydrogen ions (H^+) concentration of extracellular fluid. The latter mechanism tends to maintain a constant Na^+ concentration/K^+ concentration ratio in extracellular fluid.

The results of the study showed that the sheep utilized 72.27% of its total water intake for evaporative cooling while the goats used 69.95% for the same purpose. Environmental temperatures ranged from 21-39°C during the period of experimentation. The two species (sheep and goat) had high evaporative water loss because the study was conducted in the hottest time of the year when minimum relative humidity was 13% and maximum was 67%. Wallace (1972) reported that Columbia wethers used 45.3-53.2% of their water intake for evaporative cooling when maintained at 20-26°C. At high environmental temperatures, evaporative water loss plays an important role in regulating body temperature. Blaxter (1962) has shown in sheep and cattle that sensible heat loss by conduction, convection and radiation fell and evaporative losses rose as the temperature difference between environment and body narrowed. Certain desert-dwelling ungulates are

physiologically adapted to allow body temperature to rise, thereby storing heat and thus lowering the requirement for evaporative losses (Taylor, 1970a and 1970b). Blaxter (1962) demonstrated in sheep that evaporative water loss was relatively constant up to 25°C, but rose steeply above that temperature. This would appear to account for the high evaporative water loss in the present study since the environmental temperature was high (maximum, 39°C).

Degen and Young (1981) reported that evaporative water loss was 38.0-55.7% of total water loss for Suffolk ewes maintained at 20°C. Degen and Young (1981) also reported that percentage of faecal water ranged between 50 and 63% for Suffolk ewes.

Schoen (1968) noted that heat stress stimulated the drinking appetite of East African goats and also induced greater reabsorption of water by the kidneys as well as by the gut.

Kinne et al. (1961) reported that, in the case of Merino sheep, under conditions of dehydration the rates of excretion of potassium and of sodium remained the same or both actually rose as water excretion decreased. The latter workers suggested that this was partly due to the influence of the hormone vasopressin.

The results of the present trial show that Nigerian Indigenous goats economise water better than their sheep counterparts.

Species and breed differences in water metabolism

Part of the present investigations were conducted to determine species and breed differences in water metabolism. Results showed a significant difference ($P<0.01$) between the water intake of sheep and goats, and also between the various breeds. This concurs with the results of King (1979) who observed significant differences in the amount of water intake and turnover among species.

The body composition of the animals were determined at the end of the study. The results show that water content of whole bodies of sheep ranged between 52.37 - 71.51% liveweight (L.W.) while values for goats were 48.16-74.69% liveweight (L.W.). Panaretto (1963) reported 34.6-72.7% liveweight (L.W.) for sheep and 55.1-75.7% liveweight (L.W.) for goats. Protein values, as percentage of L.W. ranged between 11.29-16.60 for sheep, while values for goats were 13.98-17.47% L.W. Working with European breed of sheep and goats Panaretto (1963) obtained protein values of 9.6-16.2% L.W. for sheep and 14.2-18.2% L.W. for goats. Similarly when the whole body fat content was expressed as percentage of L.W. 11.31-29.80% for sheep and 3.56-33.03 for goats were obtained. Panaretto (1963) obtained 5.8-52.4% for sheep and 2.0-25.3% for goats. Whole body ash obtained for the sheep in the present trial ranged between 2.62-4.63% L.W. while 2.67-7.09%

was obtained for goats. Panaretto (1963) obtained 2.5-5.2% L.W. for ash in sheep and 3.8-5.7% L.W. for goats. Ranjhan et al. (1982) reported 65.8% L.W. as water, 13.4% L.W. as protein, 13.2% L.W. as fat and 4.1% L.W. for ash in Muzaffarnagri breed of sheep.

There appears to be a wide range in whole body fat for goats. Moulton (1920) recorded a fat content of 1.9% L.W. in an 11-months - old steer; Widdowson et al. (1951) found 1.1% fat in human cadaver; and Rathbun and Pace (1945) found a fat content of 1% in guinea-pigs.

Total body water is the key composition of the living ruminants as it is in monogastric animals (Panaretto and Till, 1963). The mean water content of the empty body (% EBW) of the Ouda was 61.8, 56.5 for Yankasa, 68.1 for Sahel goats and 51.6% for Maradi. This agreed closely with the mean of 57.3% for sheep and 57.66% for goats reported for other breeds by Panaretto (1963).

The measurement of total body water and water turnover based on the tritiated water dilution technique described by Macfarlane et al. (1966) and modified by Springell and Wright (1976) was employed and well validated in the present studies. TOH space overestimated total body water and consequently a correction factor of 0.85 was used in the calculation of body water. This is in line with the findings of Panaretto and Till (1963), King et al. (1978), Smith and Sykes (1974), Ranjhan et al. (1982).

The TOH spaces (kg) were related to total body water (kg), the correlation coefficient being 0.992 (Y = 0.353 + 0.841X). TOH space was least for Maradi goats (66.1% L.W.), while the values for Sahel goats, was 77.8% L.W. TOH space values for Yankasa and Ouda sheep were 73.6 and 80.5% L.W. respectively. These closely agree with the results of Ranjhan et al. (1982) who reported TOH space (% L.W.) of 76.5, 77.4, 71.9 in Muzaffarnagri, Muzaffarnagri X Dorset and Muzaffarnagri X Suffolk breeds of sheep in India. Panaretto (1963) obtained TOH spaces (% L.W.) of 36.8-74.2 for sheep; and 55.6-75.7 for goats. The biological half-life of tritium was least in Yankasa (115.h) and longest in Sahel (173.h). Ranjhan et al. (1982) reported buological half-life of tritium as 97.66h in crossbred sheep and 134.30h in goats. Water turnover rates per day/animal (litres) were 2.52, 2.63, 0.86 and 1.09 for Ouda sheep, Yankasa sheep, Sahel goats and Maradi goats breeds respectively. These findings agree closely with the results of Aggrey (1982) in West African dwarf sheep and goats in Ghana. Aggrey (1982) obtained 2.06L for sheep and 1.28L for goats as water turnover rates in the dry season. Macfarlane et al. (1966) suggested that water turnover is linked with the use of water for metabolic processes and may be correlated with the synthesis of protein and energy. Macfarlane

et al. (1966) further suggested that water turnover was related more to energy turnover than heat dissipation in tropical animals. Lower water turnover rates in goats than in sheep suggests that under poor dry conditions goats are better adapted for survival than sheep. The fact that the water turnover of Sahel goats was the lowest suggests that under conditions where supplies of drinking water are limited they would be the more suitable breed for production.

Diet effect on water metabolism

The relationship between dry matter and water intake is well established (Leitch and Thompson, 1944) in many species of farm animals. Cattle have been reported to drink more on a high protein diet with a consequent higher output of urine to allow for the removal of nitrogenous waste (ARC, 1980). High intake of water has been said to raise the rate of passage of food through the digestive tract (Koes and Pfander, 1975) which adversely affects digestibility. Reynolds (1983) reported high total water-exchange, associated with elevated dietary nitrogen as opposed to increased dry matter intake in East African goats.

Five experiments were conducted to study diet effects on water metabolism. The first trial was to test the influence of different types of feed on water metabolism in sheep and goats. Results of the

trial show a significant ($P<0.01$) difference in water intake between sheep and goats on the various diets. Sheep on hay + concentrate mixture drank 1257.4ml of water daily which was significantly ($P<0.01$) higher than for the other groups. This might be due to the higher protein contents of the diet. The animals on the hay + concentrate diet need more water to excrete nitrogenous waste. This is in line with the reports of ARC (1980) on cattle on high protein diet. Goats fed on hay only, had high water intake. This may have been to increase the rate of passage of the hay through the gut as was reported by Koes and Pfander (1975). There was no significant ($P>0.05$) difference between goats fed on hay + whole maize and hay + ground maize. The protein content of the two rations were essentially the same and the only difference was the particle size of maize which did not affect the water intake of the goats.

Water requirements varied with type of feed in the present study, indicating that water that may appear adequate at one time for a particular diet could be insufficient for another. The present findings also show a decrease in roughage intake with increase in concentrate mixture or maize consumption. The dry-matter intake did not differ significantly between treatments for each specie.

Further trials carried out tested the effect of feed restriction on water metabolism. The studies showed a highly significant ($P<0.01$) effect of feed intake on water intake of the animals. The results also indicate that the amount of water intake of sheep is dependent on the amount of feed intake (DM basis); and confirmed findings of Phillips (1960), Clark and Quin (1949) that emphasized the close relationship between water and food intake. The latter workers found that among Merino sheep near Pretoria, reduction of food intake lessened water consumption; and a reduction in available water was also associated with less food consumption. Macfarlane and Howard (1972) also observed that feed restriction in ruminants limit water intake. Anand (1961) pointed out that this linkage of functions arises in part from the interaction of neighbouring neurones of the ventro-medial hypothalamus where food and water intake is regulated on afferent information and blood composition.

Feed management designed as variations in concentrate to roughage ratios and processing methods also significantly influenced water intake.

Water intake of the animals varied with the ratio of concentrate to roughage ratio in their diet. The total dry matter (DM) intake of the sheep and goats on the different diets were about the same. The DM intake of the sheep was higher than the goats on

corresponding diets. There was a linear increase in water intake of the animals with an increase in the concentrate content of the diet. The variation in concentration appear to result in variations in the crude protein intake of the animals. The animals on 70% concentrate were getting higher crude protein intake than those on 30% concentrate. Consequently, they required more water to clear nitrogenous waste out of the kidneys. The latter agree closely with the reports of Reynolds (1983) who stated that liquid-water consumption was positively correlated with nitrogen intake. Phillips and Dyck (1964) found a marked effect of ration types and combinations on flow rate of digesta in the reticulo-rumen. Although no cannulation study was done, the reasons for variations in water consumption in the trial could be deduced from the different protein content of the diets and also the flow rate of ingesta as evident from the findings of previous workers (Phillipson et al. 1949).

In the trial on feed processing, the results show a significant difference ($P < 0.01$) in water intake of sheep fed on milled and unmilled concentrate. The sheep on milled concentrate and chopped hay consumed more feed than the others which meant that they had higher crude protein intake on the whole. Consequently, they required more water for excretion processes. Also milling the

feed might have affected the flow-rate of the ingesta in the gut. The results of all the trials confirm that water intake of Nigerian sheep and goats are influenced by diet types combinations and processing methods.

Physiological changes in water metabolism

Age effects on water requirements of sheep and goats showed significant differences ($P \leq 0.01$) with regards to water intake. Also female goats drank more free water than the male goats but the difference was not statistically significant.

Generally sheep drank more water per metabolic size than the goats while the older animals drank more than the young ones. The older animals were bigger in body size and consequently they required more water. This finding is in line with that of Crampton and Harris (1969) who observed that older animals consumed more feed and as a result, required more water for proper digestion and utilization of the feed. The study also confirms a variation in water requirement with age of goats and sheep but no conclusion could be made for any relationships between sex and water requirement.

The results of water intake of ewes under various physiological states show that lactating ewes drank more water than the pregnant and non-pregnant ewes. Macfarlane and Howard (1972) reported that lactating Merino ewes produced about 1.2 litres of milk daily to feed the lambs. These workers further stated that

the water turnover of the ewes was accordingly increased by the amount of metabolic water produced in milk synthesis. This increased the ewes' water turnover by 44% for lactation relative to non-lactating and non-pregnant ewes. Water intake of the pregnant ewes were slightly higher than the non-pregnant ewes but significantly lower than that of the lactating ewes. Macfarlane and Howeard (1972) pointed out that water turnover during pregnancy was virtually the same as that of non-pregnant Merino ewes. Water deprivation seriously affected the reproductive performance of Yankasa ewes. Abortion and stillbirth occured in the water deprived ewes. Pregnant ewes receiving daily watering had heavier lambs at birth. The latter is in agreement with findings by Lynch et al. (1972) who reported a significant reduction in the birth weight of the lambs of ewes deprived of drinking water. The present study shows the importance of adequate water supply to lactating ewes to enhance optimum milk production. It also showed that water is very important for pregnant ewes to maintain the pregnancy and also for lamb survival.

In all the experiments where physiological parameters like jaw movement, respiratory rate, rectal temperature, pulse rate were measured, results show that water intake significantly influenced each of these.

Variations in rectal temperature was slight and this agreed closely with the findings of Bligh (1972) who reported that sheep have an exceptionally constant body temperature with total variations of less than $2^{o}C$ even between seasons.

Respiratory rate, pulse rate and jaw movement, as measurements of metabolic activity decreased significantly ($P<0.01$) with water deprivation. The decrease in metabolic activities is a major adaptive mechanism in desert animals to reduce body heat load as a means of regulating body temperature (Hudson et al. 1972). This will be reflected in a reduced utilisation of water for evaporative temperature regulation which takes 72.27% of total water intake of Yankasa sheep as shown in the present investigations. Respiratory rate and jaw movement decreased significantly ($P<0.05$) with feed restriction. This could be a result of reduced energy available for metabolic purposes in animals under feed deprivation. A reduction in jaw movement could indicate a decrease in rumination and consequently digestibility of the feed (Gordon, 1965).

Blood components and biochemical values were determined for the experimental animals under various treatments. Reports on the biochemical components of small ruminants under various nutritional states are scanty. Few works by Oduye (1976) on Nigerian dwarf

sheep, Saror and Schillhorn Van Veen (1977) and Esievo et al. (1984a, 1984b) on lambs and kids, considered only the blood picture and no work was done on blood biochemical values.

No significant differences were detected between breeds in all the parameters measured. Significant differences ($P \leq 0.05$) existed between the values for sheep and goats in most of the parameters measured namely plasma chloride, magnesium, potassium, sodium, albumin, Blood urea nitrogen, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) red blood cell (RBC) and alkaline phsophatase. Blood component and biochemical values were similar for all breeds possibly because they were subjected to the same feeding and management. Hewett (1974) observed variations in blood components between and within herds and concluded that the variation depended upon the type, quality and intensity of feeding, hygiene and other management factors. Little and Manston (1972) found that serum urea nitrogen and albumin levels varied with the type of silage fed. Saror and Schillhorn Van Veen (1977) reported that the haematology of sheep is not known to be significantly influenced by breed differences. The latter, further stated, that, the health status, feeding and management conditions were more important than breed for differences in haematological values of sheep. Blood components of

the grazing experimental sheep were significantly ($P<0.05$) affected by season. This is likely to be due to the differences in quality of grazed pasture in the two (wet and dry) seasons. Pasture is of high quality in the wet season with about 12% crude protein and 2.75% CP in the dry season. Greig and Boyne (1956), using identical twins showed that cows on a low plane of nutrition had low haemoglobin levels. Prewitt et al. (1971) related the level of serum urea nitrogen to protein intake. In the present studies, values ranging from 26-30% were obtained for PCV, which agrees closely with results of Anosa and Isoun (1976) in healthy dwarf goats and sheep. Nettleton and Beckett (1976) reported a mean PCV value of 29% for indigenous goats in Swaziland. Total protein values of 6.9-7.1g/dl were obtained for sheep, and 6.6-6.8g/dl for goats; which are slightly higher than 5.2-5.9g/100ml for dwarf sheep and 4.75 - 5.43g/100ml for dwarf goats reported by Anosa and Isoun (1976). Haemoglobin values obtained in the present study were 7.5-8.0g/dl for sheep and 7.5-7.7g/dl for goats which are lower than the 10.1g/100ml reported by Nettleton and Beckett (1976) in Swaziland goats and 12.4g percent for sheep by Holman (1944) and 10.78g percent by Hackett et al. (1957) in temperate sheep. Values for RBC obtained for the animals under the various treatments varied and they were much higher in grazing animals in the wet season. Oduye (1976)

reported that RBC values decreased with age in both Nigerian dwarf goats and sheep. Oduye (1976) further stated that sex and pregnancy appeared to have little or no influence on the erythrocytic values. Holman and Dew (1963) observed a decrease in RBC values with advancing age in goats. A mean total WBC count of 7.7×10^3, 8.05×10^3, 7.5×10^3 and 7.74×10^3 were obtained for Ouda, Yankasa, Sahel and Maradi breeds respectively. Holman and Dew (1963) reported a mean total WBC count of 8.08×10^3 while Millsen et al. (1960) observed a range of 9.00×10^3 to 15.00×10^3 in the goat. In temperate sheep, the mean WBC count was 9.2×10^3 (Holman, 1944) or 9.95×10^3 (Hackett et al. 1957). Edwards et al. (1955) recorded a mean WBC count of 14.54×10^3 and 14.23×10^3 in West African dwarf goats and sheep respectively in Ghana. Mean corpuscular haemoglobin concentration of 28.57, 27.5, 28.68 and 26.18 were obtained for Ouda and Yankasa sheep, Sahel and Maradi goats respectively. The latter agree with the results of Idris et al. (1976) who obtained 25 to 40 percent for sheep in Gezira Province and the 34.9% reported by Nettleton and Beckett (1976) for indigenous goats in Swaziland.

Reports of serum alkaline phosphatase concentrations in indigenous Nigerian goats and sheep are scanty. Results obtained for alkaline phosphatase were 73.9,

55.3, 73.4 and 63.8 (Armstrong units/litre) A.U./L for Ouda and Yankasa sheep, Sahel and Maradi goat breeds. It is therefore difficult to compare these result with any others. Plasma sodium and potassium values obtained were in line with the findings of Idris et al. (1976) who reported 3 to 6 meq/L for potassium and 130 to 150 meq/L for sodium in sheep in the Gezira province of Sudan. Plasma potassium and chloride levels were higher in they dry season compared to the wet season. This confirmed the findings of Akerejola et al. (1980) who reported seasonal variations in chloride, potassium and blood urea nitrogen levels of cattle in Northern Nigeria. Significantly higher plasma concentrations of magnesium were obtained in the dry season than the wet season in the grazing sheep. The latter is in line with the finlings of Akerejola et al. (1980) in zebu cattle. Variations found between seasons in the present studies agree with Saror and Coles (1973) who reported seasonal differences in nutrition in grazing Nigerian cattle. Whiby et al. (1978) cibted by Ghodi and Chechet (1981) reported that blood urea concentrations are known to vary widely and are affected by various factors such as dietary protein levels, the rate of protein catabolism, health status of liver and renal function of the kidney.

Water deprivation

The intake of water is intermittent while the loss of water is continuous thus, the animals is always faced with the problem of slow dehydration. Houpt (1977) stated that after a long period of dehydration the animal will be depleted of both water and primary electrolytes.

Two trials were conducted to study the effect of water deprivation in Yankasa sheep. The first trial examined the influence of intermittent watering on grazing sheep while the second trial investigated the response of Yankasa ewes under various physiologic states to water deprivation.

Results of the trial on grazing sheep show that intermittent watering has a negative effect on the growth rate of the experimental animals during the dry season. The animals lost weight except those on daily watering which gained 66g daily. During the rainy season all animals gained weight despite the watering intervals imposed on them. The latter would appear to be due to the high moisture content of the pasture (about 80%). The effect of water deprivation was obvious only during the dry season trial. The observed decrease in mean live-weight gain with increased water deprivation confirmed the data of Umunna et al. (1981) with sheep deprived of water during the dry season. The animals on 72h and 96h watering intervals grew less

and staggered whenever they attempted to graze and this became pronounced towards the end of the study. The hair coat was rough and dry, it pulled off easily by mere touching after the experiment had progressed for 40 days. This observation agreed closely with the findings of Schoen (1968) who reported skin dehydration and hair loss in water deprived East African goats.

Water deprivation raised blood biochemical constituents significantly. This is in agreement with the report of Whitby et al. (1978) cited by Ghodi and Chechet (1981) who stated that raised plasma total protein may occur as a result of dehydration. Osori (1976) reported high levels of total protein, albumin, globulin, sodium and potassium in sera of cattle and he attributed it to dehydration of the animals as a result of the prevailing drought at the time the study was conducted. Houpt (1977) stated that haemoconcentration can result due to dehydration of animals.

The serum protein fractions in the ewes' blood were affected by water deprivation. The mean albumin, alpha-globulin, Beta-globulin and gamma-globulin values were higher than those reported by Anosa and Isaun (1976) for healthy Nigerian dwarf sheep. The high values obtained in water deprived ewes show signs of haemoconcentration due to dehydration.

All the blood biochemical components increased with increased water deprivation in pregnant, non-pregnant and lactating ewes.

Prolonged watering intervals appeared to exert serious stress on the animals during the dry season. Variations in rectal temperature was slight between the animals on various watering intervals. This agreed closely with the findings of Lee and Robinson (1941) who investigated the ability of a variety of common domestic animals to withstand high environmental temperatures and concluded that sheep had the greatest tolerance. Lee and Robinson (1941) stated that the principal adaptations are an ability to endure a degree of dehydration equal to about 30 percent of body weight and to minimize absorption of solar heat.

A decrease in urine output and production of dry faeces were observed with the water deprived animals during the dry season. The latter observations are in line with the findings of Macfarlane et al. (1958) who found that sheep conserve water by excreting dry faeces and a relatively concentrated urine. Also, dissipation of heat by evaporation of water is effected primarily by panting and very little sweating in a situation of water deprivation in sheep (Macfarlane et al. 1958).

The water deprived animals in the trial appeared to be drinking in a compensatory fashion whenever they had access to drinking water. This observations

confirms the findings of Macfarlance et al. (1958) who reported that sheep behave similar to camels and donkeys in being able to drink nearly one fourth of its body weight of water at one instance without harmful effects. More and Sehni (1978) also reported cummulative drinking behaviour in chokla lambs.

Water deprivation also significantly lowered respiratory rate in sheep. Also jaw movement was drastically reduced with long watering intervals which indicated that rumination was seriously impaired by water deprivation. This confirmed the results of Gordon (1965) who reported that rumination decreased in water-restricted sheep. The lactating ewes were significantly ($P \leq 0.01$) affected by water deprivation, since the milk yield dropped and growth rate was also severely lowered. Results on milk composition indicated that milk was about 80% water. Water restriction affected both milk yield and composition. Ewes on daily watering produced the highest quantity of milk. Milk production decreased with increased watering intervals. Milk production of the ewes dropped by more than 50% when watering intervals was increased to 72hours, compared with daily watering. The milk produced by water-deprived ewes was more viscous. Consequently, the composition of the ewes' milk for protein, fat, ash, non-fat solid (solid not fat) and total solids increased with increased water restriction.

Devendra (1982) reported that nutrition represents the single most important factor that causes variations in milk composition in the lactating goat. Water deprivation depressed the feed intake of the ewes significantly consequently, affecting their plane of nutrition. Stulies on Barbari and Jamnapari goats in India and Alpine goats in France showed that an increase in plane of dietary energy also resulted in increased milk yield (Sacheva et al. 1974; and Morand-Fehr, 1977). For optimum milk production, water should be given to lactating ewes daily (and preferably ad libitum where possible) to enhance milk production.

The reproductive performance of the pregnant ewes was adversely affected by water deprivation. Abortion rate increased with water deprivation and the only stillbirth was recorded under 72h watering. Lamb mortality was highest with ewes most deprived of drinking water. Pregnant ewes subjected to 72h watering appeared uncomfortable, very nervous and showed more frequent bleating. These observations confirmed the results of More and Sahni (1978) who reported that 4 out of 5 chokla ewes watered once in 96h aborted. Lambs from the water-deprived ewes in the present stuly weighed less than the lambs of ewes which had regular access to drinking water. Non-breeding ewes drank less than pregnant and lactating ewes. This finding is in line with the observation of More and Sahni (1978) with chokla ewes.

Jaw movement decreased during re-mastication of feed with increased water deprivation in sheep. Gordon (1965) stressed the importance of water for rumination. The plentiful and continuous supply of water to the reticulo-rumen is provided mainly by recirculation as saliva and partly by the drinking of water. Denton (1957) reported that salivation is reduced during water deprivation and starvation.

The present investigation has demonstrated possible adaptive mechanisms of some indigenous Nigerian sheep and goats to various levels of water availability. The indication also is that some of the breeds are more adapted to arid conditions. The influence of various physiological states (eg pregnancy and lactation) on water metabolism were highlighted.

It can also be concluded from the results of these studies that water deprivation hampers the process of rumination and consequently reducing digestibility of feed. Thus water deprivation would lower milk yield of lactating ewes, impair reproductive performance of pregnant ewes and survival of new born lambs. These point to the need for adequate water supply to ruminant operations.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

Nine feeding experiments and one metabolism study were carried out to investigate water metabolism of some indigenous Nigerian sheep and goats in the Sudan Savanna zone of Nigeria. In one of the feeding experiments two breeds of sheep namely Yankasa and Ouda and two breeds of goats, Sahel and Maradi were used. Isotope dilution study was done on the four breeds to examine if there was any variation in water metabolism due to breed. Isotope used was tritium (H^3) as tritiated water (TOH). Results obtained indicate that water metabolism depended on the specie. Water intake in sheep and goats was also influenced by environmental conditions. The greatest intake occured during the hot dry season, and the least during the rainy season. Sheep consumed relatively more water than goats. Water intake was strongly affected by diet and plane of nutrition. Tritiated water space averaged 66.1% in Maradi goats, 77.8% in Sahel, 73.6% in Yankasa and 80.5% in Ouda. The biological half-life of tritiated water was least in Yankasa (4.8 days) and longest in Sahel goats (7.2 days).

Seasonal variations in water requirements of grazed Yankasa sheep were also studied. The results showed that grazing animals required more water in the dry hot season compared to the rainy season. Water deprivation resulted in 40% loss of body weight in grazed Yankasa sheep in

the dry hot season while in the rainy season the animals put on weight due to the water content of fresh grown pasture. The results showed that grazing sheep do not need to be watered daily in the wet season since the pasture contained 70-80% moisture. Under 96h watering intervals in the rainy season the animals performed adequately. Water deprivation constitutes a serious nutritional stress in the hot, dry season, Water deprivation resulted in decreased total body water as evident by the loss in body weight and also with evidence of hemoconcentration. This was shown by increased PCV, total red blood cells, Hb, total proteins, blood urea nitrogen and plasma sodium, potassium, magnesium and chloride. Water deprivation also induced variation in body temperature which rises during the day although variations was not more than 3 ^{o}C. Physiologic defence mechanisms were employed to reduce the effects of water deprivation. Respiratory rate and faecal moisture content were reduced to minimised water loss. Amount of urine voided was also drastically cut down under water deprivation. The physical activities of the water-deprived animals were reduced. All these were physiological methods of surviving water stress by small ruminants.

Milk yield of water deprived lactating ewes dropped, pregnant and water deprived ewes were nervous

and restless which led to abortions, low birth weights and high mortality of newly born lambs.

Feed restriction arrested water intake in sheep and this show that feed intake is closely associated with water intake.

The results of the water turnover study showed that goats had the least turnover rate and indicate that under conditions of water inadequacy goats would be more suitable specie than sheep.

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APPENDICES

Appendix 1.1: Water balance of Yankasa sheep and Maradi goats under ad libitum water supply.

ANOVA

Source	d.f.	Mean squares		
		Water drunk ml/ $kg^{0.73}$/day	Urine ml/$kg^{0.75}$/day	Faecal water loss
Treatment	1	70267**	219.38*	968.79***
Residual	110	2561	51.46	14.99
Total	111	3171	52.97	23.58

*P<0.05 **P<0.01 ***P<0.001

Appendix 1.2: Water balance of Yankasa sheep and Maradi goats under ad libitum water

ANOVA

Source	d.f.	Mean squares		
		Water intake in food (ml/kg$^{0.73}$/day	Metabolic water ml/kg$^{0.73}$/day	Evaporated water loss ml/kg$^{0.73}$/day
Treatment	1	0.357013***	8.6320**	3541.5**
Residual	6	0.004829	0.5350	180.4
Total	7	0.055141	1.6917	660.6

**P<0.01 ***P<0.001

Tritium counts (d.p.m)

Experiment 2: Hours after injecting tritiated water (TOH) into experimental animals

Species	Breed	Replicates	6	12	18	24	30	36	45	51	57	69	81	93	117	141	165
						24											
Sheep	Cuda	1	2232	2344	2816	3560	2808	2608	2280	2232	2200	2128	1984	1960	1632	1592	1[illegible]
		2	2256	2376	2496	3864	3304	2584	2400	2240	2064	1888	1872	1840	1750	1600	1544
		3	2224	2480	2680	3168	2776	2696	2480	2376	2220	2256	2160	2096	1776	1616	1456
		4	1824	2464	2512	3240	3104	2816	2504	2400	2312	2224	2128	1920	1816	1552	1520
		Ave.	2134	2416	2626	3460	2998	2676	2416	2312	2214	2124	2036	1954	1746	1590	1472
Sheep	Yan-kasa	1	2336	2520	3008	3592	3312	2648	2520	2352	2336	2296	2208	2048	1952	1752	1544
		2	2400	2720	3312	4264	3112	2992	2752	2520	2344	2312	2168	2096	1776	1552	1376
		3	2464	3072	4432	4128	3168	2904	2840	2632	2408	2328	2128	1904	1725	1560	1580
		4	2560	3248	3928	4504	3472	3160	2852	2752	2600	2400	2240	1936	1848	1784	1512
		Ave.	2440	2590	3670	4256	3506	2992	2757	2616	2478	2354	2478	2952	1880	1704	1486
Goats	Maradi	1	2624	2992	3480	3640	3800	3660	3500	3400	3232	2560	2324	2228	2086	1888	1548
		2	2472	2848	3024	3408	3628	3256	3052	2632	2408	2316	2112	2018	1932	1752	1540
		3	2528	2944	3092	3224	3660	3506	3416	3216	2864	2480	2268	2008	1824	1656	1524
		4	2360	2824	2696	3076	3682	3512	3456	3016	2646	2404	2232	1116	2060	1864	1442
		Ave.	2496	2852	3073	3337	3692	3483	3356	3066	2807	2440	2234	2092	1975	1790	1539
Goats	Sahel	1	2304	2560	3056	3224	3495	3280	3145	3006	2920	2744	2528	2400	2400	2208	2032
		2	2328	2464	2760	3088	3455	3320	3220	2816	2536	2284	2248	2124	2028	1864	1692
		3	2240	2392	2528	2752	3216	3136	3170	3160	2952	2428	2224	2120	1875	1748	1688
		4	2288	2528	2704	3320	3404	3360	3264	3000	2864	2592	2360	2208	2026	1935	1880
		Ave.	2290	2486	2762	3096	3393	3295	3199	2995	2838	2556	2336	2245	2081	1939	1818

Appendix 2.1: Effect of breed on water metabolism in penned sheep and goats.

ANOVA

Source	d.f.	Means squares (TOH)Tritiated water space.	(TBW) Total body water
Treatment	3	2355.3***	1781.9***
1,2 Vs 3,4	1	1533.2*	1107.7*
1 Vs 2	1	1440.7*	1040.9*
3 Vs 4	1	4092.7***	2957.0***
Residual	236	344.1	248.6
Total	239	369.3	266.9

*P$\leq$0.05

***P$\leq$0.001

Appendix 2.1.1: Correlation matrix of TOH space and body composition of sheep and goats.

		1	2	3	4	5
1.	Liveweight (kg)	1				
2.	Total body water (kg)	-0.034	1			
3.	Body protein(kg)	-0.728	0.402	1		
4.	Body fat (kg)	0.379	0.904	-.699	1	
5.	TOH space (Percent live wt)	0.178	0.921	0.203	-0.75	1

Appendix 2.1.2: Effect of breed on water metabolism in penned sheep and goat (composition of whole bodies)

ANOVA

Source	d.f.	Mean squares			
		Body water (as percent liveweight)	Body protein	Body Ash	Body fat
Treatment	3	176.76	8.481*	0.1358	187.17
1,2 Vs 3,4	1	11.32	17.766*	0.2475	59.87
1 Vs 2	1	89.11	0.98	0.1596	55.97
3 Vs 4	1	429.83*	6.698	0.0002	445.66*
Residual	12	53.20	1.731	0.2043	26.69
Total	15	77.91	3.081	0.1906	74.79

*P<0.05

Appendix 2.:2:Effect of breed on water met-bolism in penned sheep and goats

ANOVA Source	d.f.	Mean squares Plasma chloride	Plasma magnesium	Plasma sodium	Plasma potassium
Treatment	3	525.942***	0.58895***	44.974***	2.01351***
1,2 Vs 3,4	1	1334.575***	0.99475***	0.480	5.92208***
1 Vs 2	1	176.584***	0.50750***	23.602*	0.02344
3 Vs 4	1	66.667***	0.2545***	105.84***	0.095
Residual	44	5.509	0.01875	7.257	0.05854
Total	47	38.728	0.05518	9.664	0.18332

Appendix 2.2.1: Effect of breed on water metabolism in penned sheep and goats

ANOVA

Source	d.f.	Mean squares			
		Serum albumin	Blood urea nitrogen	Packed cell volume	Mean corpuscular volume
Treatment	3	0.89389***	105.0624***	32.059***	89.015***
1,2 Vs 3,4	1	0.65333***	305.5252***	0.367	102.580***
1 Vs 2	1	0.42667**	1.2604	40.300***	59.224**
3 Vs 4	1	1.60167***	8.4017***	55.510***	95.242***
Residual	44	0.06633	0.4916	1.207	7.98
Total	47	0.11915	7.1664	3.176	13.152

**P<0.01

***P<0.001

Appendix 2.2.2: Effect of breed on water metabolism in penned sheep and goats

ANOVA

Source	d.f.	Mean squares			
		Mean Corpuscular Haemoglobin concentration (MCHC)	MCH	RBC	Haemoglobin
Treatment	3	16.308*	5.2693**	1.5806***	0.5414*
1,2 Vs 3,4	1	4.508	14.4321***	4.6075***	0.2700
1 Vs 2	1	6.742	1.0584	0.8504	1.1704**
3 Vs 4	1	37.675**	0.3174	0.0037	0.1838
Residual	44	4.629	0.5293	0.256	0.1481
Total	47	5.374	0.8323	0.3406	0.1732

Appendix 2.2.3: Effect of breed on water metabolism in penned sheep and goats

ANCVA Source	d.f.	Mean squares		
		Total protein	White Blood cell	Alkaline phosphatase
Treatment	3	0.4567	475764	935.7*
1,2 Vs 3,4	1	0.9633*	541875	190.4
1 Vs 2	1	0.1667	735000	2062.8**
3 Vs 4	1	0.24	150417	553.9*
Residual	44	0.2936	432633	112.7
Total	47	0.304	435386	165.2

*P<0.05

**P<0.01

Appendix 3.1: Effect of age and sex on water requirement of penned sheep and goats.

ANOVA Source	d.f.	Mean squares Water intake
Treatment	7	65182832***
1,2,3,4 Vs 5,6,7,8	1	298247587***
1,2 Vs 3,4	1	7274374***
1,3, Vs 2,4	1	106772098***
5,6 Vs 7,8	1	1439519**
5,7 Vs 6,8	1	40990457***
1,3 Vs 5,7	1	66177839***
1,3 Vs 6,8	1	338841846***
Residual	1992	89953
Total	1999	317892

**P/0.01

***P/0.001

Appendix 3.2: Effect of age and sex on water requirement of penned sheep and goats

ANOVA

Source	d.f.	Mean Squares	
		Average daily gain (ADG)	Daily Hay intake
Treatment	7	0.004***	27282.45***
1,2,3,4 Vs 5,6,7,8	1	0.0269***	89709.31***
1,2 Vs 3,4	1	0.0000018	10.6
1,3 Vs 2,4	1	0.00048**	17844.34***
5,6 Vs 7,8	1	0.000115*	5.94
5,7 Vs 6,8	1	0.000768***	83372.78
1,3 Vs 5,7	1	0.0215***	103476.15***
2,4 Vs 6,8	1	0.0059***	4077.5***
Residual	32	0.0000255	44.15
Total	39	0.000747	4933.07

*P<0.05

**P<0.01

***P<0.001

Appendix 4.1: Performance of grazing Yankasa sheep under intermittent watering during dry and wet season.

ANOVA Source	d.f.	Mean squares Water intake	Average daily dgain
Treatment	7	1919399***	0.068714***
Seasons	1	11700316***	0.3108169***
1 Vs 2,3,4	1	67	0.0024833*
2 Vs 3,4	1	31629**	0.3108169***
3 Vs 4	1	2199	0.0002916
5 Vs 6,7,8	1	1532802***	0.10584***
6 Vs 7,8	1	141948***	0.0519168***
7 Vs 8	1	26832	0.0080656***
Residual	32	2473	0.0003692
Total	39	346537	0.0126362

*P<0.05
**P<0.01
***P<0.001

Appendix 4.2.1: Blood Biochemistry of grazing Yankasa sheep under intermittent watering during dry and wet season.

ANOVA Source	d.f.	Mean squares PCV	MCH	MCHC	MCV
Treatment	7	110.058**	80.398***	329.195***	156.383**
Seasons	1	42.136*	427.226***	2169.692***	324.488**
1 Vs 2,3,4	1	8.333	14.905**	4.814	124.846***
2 Vs 3,4	1	33.607	91.166***	5.23	507.509***
3 Vs 4	1	21.78	28.637***	35.803**	81.179**
5 Vs 6,7,8	1	321.575**	9.048	20.856*	17.715
6 Vs 7,8	1	307.021	0.056	45.927**	36.015*
7 Vs 8	1	35.955*	0.744	22.045*	3.938
Residual	192	8.402	1.106	3.075	8.757
Total	199	11.978	3.856	14.546	13.95

*P<0.05
**P<0.01
***P<0.001

Appendix 4.2.1.1: Blood Biochemistry of grazing Yankasa sheep under intermittent watering during dry and wet seasons.

ANOVA

Source	d.f.	Mean Squares				
		Total protein	RBC	WBC	[illegible]	Hb
Treatment	7	0.8939	17.0225	39920000		.4781285***
Seasons	1	3.5112	6.6832	417700000***		282.7442***
1 Vs 2,3,4	1	1.2416	5.3922*	5824000		0.1728
2 Vs 3,4	1	0.1121	66.8268***	155900000***		3.1104
3 Vs 4	1	0.0242	2.7375	1009000		14.3548***
5 Vs 6,7,8	1	0.9185	21.0251	4750000		17.5692***
6 Vs 7,8	1	0.3851	14.6453**	10670000		11.9286**
7 Vs 8	1	0.0646	1.847	33620000		0.0098
Residual	192	0.4014	0.8643	34020000		0.8515
Total	199	0.4188	1.4325	35990000		2.4793

*P/0.05
**P/0.01
***P/0.001

Appendix 4.2.1.2: Blood Biochemistry of grazing Yankasa sheep under intermittent watering and during dry season.

ANOVA

Source	d.f.	Mean squares		
		Blood urea nitrogen	Serum albumin	Alkaline phosphatase
Treatment	3	112.372***	0.1729	2070.5
1 Vs 2,3,4	1	244.099***	0.3675	1379.0
2 Vs 3,4	1	81.402***	0.135	26.5
3 Vs 4	1	11.616*	0.0162	4805.9**
Residual	96	2.843	0.1574	910.4
Total	99	6.162	0.1578	945.6

*P<0.05

***P<0.001

Appendix 4.2.2: Plasma minerals of grazing Yankasa sheep under intermittent watering during dry and wet seasons.

ANOVA

Source	d.f.	Mean squares			
		Plasma potassium	Magnesium	Sodium	Chloride
Treatment	7	17.4455***	3.2122***	358.093***	693.31***
Seasons	1	111.542***	19.92698***	1206.978***	3623.56**
1 Vs 2,3,4	1	2.0336**	0.01255	26.94	151.09***
2 Vs 3,4	1	6.0401***	0.07707	28.08	144.45***
3 Vs 4	1	0.1458	0.2312	0.696	14.36
5 Vs 7,8	1	1.0396*	2.00247**	746.394	210.00***
6 Vs 7,8	1	0.2948	0.00913	491.777	367.54***
7 Vs 8	1	1.0225	0.21912	5.917	342.17***
Residual	192	0.1596	0.06997	8.277	11.54
Total	199	0.7589	0.18047	20.582	35.52

**P<0.01

***P<0.001

Appendix 4.3: Physiologic parameters of grazing Yankasa sheep under intermittent watering during dry and wet seasons.

ANOVA

Source	d.f.	Mean squares		
		Rectal temperature	Respiratory rate	Jaw movement
Treatment	7	5.5439**	1327.29***	9693.9***
Seasons	1	25.3726***	625.83***	11268.11***
1 Vs 2,3,4	1	2.2012**	742.98***	8140.74**
2 Vs 3,4	1	0.0344	614.44***	3631.49***
3 Vs 4	1	0.0183	196.83**	1478.75***
5 Vs 6,7,8	1	5.408**	5647.24***	29134.3***
6 Vs 7,8	1	4.18**	1448.57***	11139.45***
7 Vs 8	1	1.5858**	15.11	3064.46***
Residual	552	0.1575	20.51	84.14
Total	559	0.225	36,87	204.48

**P<0.01

***P<0.001

Appendix 4.4.1: Proximate analysis (%) of samples from the pastures grazed by experimental animals during the wet season (DM basis)

Collection times	1	2	3	4	5	6	7	8	9	10	11	Mean
Dry matter	20.4	42.1	21.3	18.9	19.8	19.1	22.4	23.4	21.1	20.3	19.3	20.9
Ash	11.3	8.8	11.5	8.0	13.4	8.8	11.3	10.3	10.4	11.7	10.7	10.6
Ether extract	5.7	4.9	4.4	4.3	4.9	5.7	5.6	6.3	5.6	5.3	5.1	5.3
Crude fibre	25.9	19.8	22.0	25.5	22.1	27.9	20.0	26.0	18.5	26.1	25.5	23.6
Nitrogen free extract (NFE)	43.4	53.9	50.7	51.6	49.1	42.6	47.0	41.0	56.7	41.5	47.1	47.8
Crude protein	13.7	12.6	11.4	10.6	10.5	15.0	14.7	15.4	8.8	14.4	11.6	12.7

Appendix 4.4.2: Proximate analysis (%) of samples from the pastures grazed by experimental animals during the dry season (DM basis)

Collection times	1	2	3	4	5	6	7	8	9	10	11	Mean
Dry matter	90.5	89.7	89.8	92.5	93.0	94.2	94.7	95.0	93.8	96.0	94.6	93.1
Ash	8.2	8.8	9.0	9.3	9.5	9.1	9.8	10.0	10.4	9.4	9.9	9.4
Ether extract	2.0	1.8	1.8	1.7	2.1	1.5	1.3	1.0	1.7	11.4	1.8	1.6
Crude fibre	38.1	37.2	38.2	37.9	38.8	39.0	39.1	39.6	39.0	39.9	37.2	38.5
Nitrogen free extract (NFE)	40.7	49.3	48.0	47.9	46.6	47.4	46.5	46.3	45.9	46.4	48.1	47.4
Crude protein	3.0	2.8	3.0	3.2	3.0	3.0	3.3	3.1	3.0	2.9	3.0	3.0

Appendix 5.1: Influence of diet type on water intake of sheep and goats.

ANOVA		Mean squares
Source	d.f.	Water intake
Period	1	5376602***
Treatment	7	21539899***
1,2,3,4, Vs 5,6,7,8	1	132756484***
1 Vs 2,3,4	1	1995267***
2,3 Vs 4	1	9939020***
2 Vs 3	1	334662*
5 Vs 6,7,8	1	2935801***
6,7 Vs 8	1	2707500***
6 Vs 7	1	110556
Period X Trt.	7	1182956***
Residual	1584	70541
Total	1599	172716

*P<0.05

***P<0.001

Appendix 5:2: Influence of diet type on water intake of sheep and goats

ANOVA	d.f.	Mean squares	
		Average daily gain (ADG)	Daily hay intake
Treatment	7	0.0043317***	58337.6***
1,2,3,4 Vs 5,6,7,8	1	0.01642578***	248822.8***
1 Vs 2,3,4	1	0.00999076***	74904.6***
2,3 Vs 4	1	0.00026667***	538.5*
2 Vs 3	1	0.00000312	25.9
5 Vs 6,7,8	1	0.00251576***	33894.3***
6,7 Vs 8	1	0.00110026***	158.9
6 Vs 7	1	0.00001953	13.0
Residual	24	0.00001367	114.8
Total	31	0.00098871	13261.9

*P<0.05

***P<0.001

Appendix 6.1: Response of Yankasa ewes under various physiologic states to water deprivation

ANOVA Source	d.f.	Mean squares
Treatment	8	819792***
1 Vs 2,3	1	32
2 Vs 5,6	1	2348378***
4 Vs 5,6	1	21035
5 Vs 6	1	1405226***
7 Vs 8,9	1	117600*
8 Vs 8,9	1	549571***
1,2,3 Vs 4,5,6,7,8,9	1	1860868***
Residual	27	28113
Total	35	209068

*P<0.05

***P<0.001

Appendix 6.2: Response of Yankasa ewes under various physiologic states to water deprivation.

ANOVA

Source	d.f.	Mean squares		
		Jaw movement	Respiratory rate	Rectal temperature
Treatment	8	2765.2***	357.352***	5.29191***
1 Vs 2,3	1	67.5	518.752***	3.79052***
2 Vs 3	1	40.22	107.256***	0.61256***
4 Vs 5,6	1	217. 35	525.008***	1.68033***
5 Vs 6	1	100.81	129.6***	1.936***
7 Vs 8,9	1	23.85	456.3***	4.40821***
8 Vs 9	1	1.41	36.1*	4.761***
Residual	711	55.48	6.944	0.07955
Total	719	85.63	10.863	0.13754

*P<0.05
***P<0.001

Appendix 6.3.1: Response of Yankasa ewes under various physiologic states to water deprivation (Sera proteins)

ANOVA Source	d.f.	Mean squares					
		Serum total protein	Serum albumin	Serum α_1-globulin	Serum α_2-globulin	Serum β-globulin	Serum γ-globulin
Treatment	8	3.1402**	0.9042**	0.06395*	0.9376	0.024575	1.10554**
1 Vs 2,3	1	0.7200	0.0035	0.00269	0.0076	0.015313	1.63202**
2 Vs 3	1	0.0067	0.4004	0.04507	0.0726	0.007004	0.51042*
4 Vs 5,6	1	0.7401	0.4201	0.04805	0.043	0.006422	2.30409***
5 Vs 6	1	0.2204	0.0204	0.02042	0.0104	0.022817	0.5046*
7 Vs 8,9	1	0.02568	0.1512	0.09317*	4.475*	0.047535	2.41267***
8 Vs 9	1	0.8437	0.0037	0.0001	0.0145	0.047704	0.23207
Residual	99	0.2374	0.1123	0.01452	0.8029	0.008033	0.08636
Total	107	0.4545	0.1715	0.118222	0.8130	0.00927	0.16264

*P$\lesssim$0.05

** P$\lesssim$0.01

***P$\lesssim$0.001

Appendix 6.3.2: Response of Yankasa ewes under various physiologic states to water deprivation (Plasma minerals)

ANOVA

Source	d.f.	Mean squares			
		Plasma sodium	Plasma chloride	Plasma potassium	Plasma magnesium
Treatment	8	49.66*	144.765***	1.6147***	1.83292***
1 Vs 2,3	1	20.59	87.781**	0.0036	0.29389*
2 Vs 3	1	15.52	90.87**	0.0009	0.00667
4 Vs 5,6	1	0.53	33.076*	0.0007	0.82347***
5 Vs 6	1	44.28*	45.375*	0.0216	0.30375*
7 Vs 8,9	1	0.78	7.605	3.1870***	0.08681
8 Vs 9	1	22.23	1.815	0.1768	0.03375
Residual	99	10.27	8.044	0.1013	0.04266
Total	107	13.22	18.266	0.2145	0.17651

*P<0.05
**P<0.01
***P<0.001

Appendix 6.3.3.1: Response of Yankasa ewes under various physiologic states to water deprivation (Blood Biochemistry)

ANOVA

Source	d.f.	Mean squares			
		Blood urea nitrogen	Haemoglobin	White Blood Cell	Red Blood Cell
Treatment	8	17.598*	10.107**	26879259*	7.7315*
1 Vs 2,3	1	24.477*	6.361*	37700139*	0.6328
2 Vs 3	1	1.460	14.415**	12470417	5.7526*
4 Vs 5,6	1	47.922*	7.031*	55827222**	26.4264**
5 Vs 6	1	3.792	8.050*	12615000	2.2940
7 Vs 8,9	1	2.304	25.92***	52702222	5.0139*
8 Vs 9	1	2.470	16.335***	166667	21.66**
Residual	99	3.356	1.013	4169251	0.9685
Total	107	4.421	1.693	5867195	1.4744

*P<0.05
**P<0.01
***P<0.001

Appendix 6.3.3.2: Response of Yankasa ewes under various physiologic states to water deprivation (Blood Biochemistry)

ANOVA

Source	d.f.	Mean squares				
		PCV	MCHC	MCH	MCV	Alkaline phosphatase
Treatment	8	125.333**	13.089	3.369	33.4	743.4
1 Vs 2,3	1	72.00**	10.975	2.283	44.75	411.4
2 Vs 3	1	181.5***	6.902	2.898	81.4*	45.7
4 Vs 5,6	1	231.125***	60.445***	8.860	5.82	6.5
5 Vs 6	1	70.042*	1.887	2.154	13.54	890.6
7 Vs 8,9	1	264.5***	1.659	7.019	84.61*	157.8
8 Vs 9	1	150.00***	1.403	1.510	9.21	315.4*
Residual	99	8.885	4.416	1.864	16.06	534.3
Total	107	17.591	5.064	1.977	17.35	549.9

*P<0.05
**P<0.01
***P<0.001

Appendix 7.1: Lifect of feed restriction on water requirement of sheep

ANOVA

Source of variation	d.f.	Mean squares Water intake
Period	1	2391743**
Treatment	2	15161084***
1 Vs 2,3	1	21792848***
2 Vs 3	1	8529320***
Period X Treatment	2	494105
Residual	594	157310
Total	599	212281

***P/0.001

Appendix 7.2: Effect of feed restriction on water requirement of sheep.

ANOVA

Source	d.f.	Mean squares	
		Average daily gain	Average daily hay intake
Treatment	2	0.00719233***	83504.710***
1 Vs 2,3	1	0.01179267***	155043.375***
2 Vs 3	1	0.002592*	11965.045***
Residual	9	0.00001278	2.162
Total	11	0.00131815	15184.444

*P/0.05

***P/0.001

Appendix 7.3.1: Effect of feed restriction on water requirement of sheep

ANOVA Source	d.f.	Mean squares			
		Serum albumin	Blood urea nitrogen	Plasma Sodium	Plasma potassium
Treatment	2	1.41646***	21.838***	46.700***	0.15997**
1 Vs 2,3	1	1.95510***	37.438***	77.580***	0.14884**
2 Vs 3	1	0.87781***	6.239	15.820*	0.17111**
Residual	45	0.02103	1.635	3.171	0.01592
Total	47	0.08041	2.494	5.024	0.02205

*P<0.05

**P<0.01

***P<0.001

Appendix 7.3.2: Effect of feed restriction on water requirement of sheep.

ANOVA

Source	d.f.	Mean squares			
		Plasma magnesium	Plasma chloride	Total protein	MCV
Treatment	2	0.016665*	11.186*	5.29083***	109.951***
1 Vs 2,3	1	0.027001*	0.260	7.82042***	127.559***
2 Vs 3	1	0.006328	22.111**	2.76125***	92.344***
Residual	45	0.004743	2.930	0.05506	5.229
Total	47	0.005250	3.281	0.27785	10.229

*P<0.05
**P<0.01
***P<0.001

Appendix 7.3.3: Effect of feed restriction on water requirement of sheep

ANOVA

Source	d.f.	Mean squares					
		Haemoglobin	MCH	PCV	WBC	RBC	MCHC
Treatment	2	37.3902***	8.9298***	400.333***	6815833***	12.4692***	2.413
1 Vs 2,3	1	57.8151***	9.6477***	620.167***	5226667**	22.6593***	4.121
2 Vs 3	1	16.9653***	8.2520***	180.500***	8405[illegible]***	2.2791**	0.705
Residual	45	0.3360	0.6797	3.978	541292	0.2902	1.395
Total	47	1.9127	1.0308	20.844	808293	0.9085	1.438

**P/0.01

***P/0.001

Appendix 7.4: Effect of feed restriction on water requirement of sheep

ANOVA source	d.f.	Mean squares			
		Pulse rate	Respiratory rate	Jaw movement	Rectal temperature
Treatment	2	2304.214***	224.720***	4765.61***	1.94292***
1 Vs 2,3	1	3867.857***	358.36***	7308.0***	3.87860***
2 Vs 3	1	740.571***	91.080***	2223.22***	0.00723
Residual	165	5.747	3.060	17.05	0.03984
Total	167	33.273	9.714	73.92	0.06263

***P/0,001

Appendix 8.1: Effect of partial feed deprivation on water metabolism of Yankasa sheep.

Source	d.f.	Mean squares
		Water intake
Period	1	61
Treatment	2	9904816***
1 Vs 2,3	1	19802613***
2 Vs 3	1	7018
Period X Trt.	2	66019
Residual	459	84818
Total	464	126882

***P/0.001

Appendix 8.2: Effect of partial feed deprivation on water metabolism of Yankasa sheep.

Source	d.f.	Mean squares	
		Average daily gain	Average daily hay intake
Treatment	2	0.00630677***	102901***
1 Vs 2,3	1	0.00910651***	197234***
2 Vs 3	1	0.00350703***	8568
Residual	9	0.00002274	4124
Total	11	0.00116529	22084

***P/0.001

Appendix 8.3.1: Effect of partial feed deprivation on water metabolism of Yankasa sheep.

Source	d.f.	Mean squares			
		Blood urea nitrogen	Serum albumin	Plasma K*	Plasma magnesium
Treatment	2	10.6575***	2.31908***	0.81526***	0.10427
1 Vs 2,3	1	14.2204***	4.63027***	1.30548***	0.000872
2 Vs 3	1	7.0947***	0.00788	0.32504**	0.019981*
Residual	54	0.2555	0.04392	0.02471	0.003462
Total	56	0.6270	0.012517	0.05294	0.003711

*P<0.05

**P<0.01

***P<0.001

Appendix 8.3.2: Effect of partial feed deprivation on water metabolism of Yankasa sheep

Source	d.f.	Mean squares				
		Plasma sodium	Plasma chloride	Total Protein	PDC	Haemoglobin
Treatment	2	96.582**	3.272	6.7153***	31.182***	2.5565**
1 Vs 2,3	1	91.221**	6.016	13.4304***	59.577***	3.9253**
2 Vs 3	1	101.944**	0.528	0.0001	2.787	1.1877*
Residual	54	6.925	3.814	0.1393	1.677	0.2596
Total	56	10.127	3.795	0.3741	2.730	0.3417

*P<0.05

**P<0.01

***P<0.001

Appendix 8.3.3: Effect of partial feed deprivation on water metabolism of Yankasa sheep

Source	d.f.	Mean squares				
		MCH	MCV	MCHC	PCV	WBC
Treatment	2	19.359***	30.15	105.124***	156.275***	3697026**
1 Vs 2,3	1	36.304***	55.07*	155.152***	247.152***	29432466*
2 Vs 3	1	2.414	5.04	55.097***	64.710***	4456186*
Residual	54	1.959	10.83	3.690	5.683	6392445
Total	56	2.580	11.52	7.313	11.062	7485465

*P<0.05

**P<0.01

***P<0.001

Appendix 8.4: Effect of partial feed deprivation on water metabolism of Yankasa sheep

Source	d.f.	Mean squares			
		Respiratory rate	Pulse Rate	Jaw movement	Rectal temperature
Treatment	2	325.689	1898.987***	17774.81***	8.18164***
1 Vs 2,3	1	649.846	3210.936***	30905.77***	14.77977***
2 Vs 3	1	1.531	587.038***	4644.65***	1.58353***
Residual	255	2.699	9.815	22.10	0.05090
Total	257	5.213	24.632	161.33	0.11377

***P<0.001

Apper'ix 9.1: Effect of concentrate to roughage ratio on water consumption of sheep and goats.

ANOVA

Source	d.f.	Mean squares
Period	1	36217227***
Treatment	7	23733340***
1,2,3,4 Vs 5,6,7,8	1	116379326***
1 Vs 2	1	7394321***
3 Vs 4	1	1034289*
5 Vs 6	1	1896955**
7 Vs 8	1	4161600***
Period X Treatment	7	601724
Residual	1584	138753
Total	1599	266634

*P<0.05

**P<0.01

***P<0.001

Appendix 9.2: Effect of concentrate to roughage ratio on water consumption of sheep and goats

ANOVA

Source	d.f.	Mean squares Average daily gain
Treatment	7	0.00643564***
1,2,3,4 Vs 5,6,7,8	1	0.0351125***
1 Vs 2	1	0.0006125***
3 Vs 4	1	0.0073205***
5 Vs 6	1	0.0002
7 Vs 8	1	0.0018
Residual	24	0.00002825
Total	31	0.00147508

***P<0.001

Appendix 10.1: Effect of feed management on water intake

ANOVA

Source	d.f.	Mean squares Water intake
Period	1	2553574***
Treatments	3	1881270**
1,2 Vs 3,4	3	2103408***
1,3 Vs 2,4	1	511162
Period X Treatment	3	58786
Residual	792	183738
Total	799	192609

**P<0.01

***P<0.001

Appendix 10.2: Effect of feed management on water intake of Yankasa sheep.

ANOVA

Source	d.f.	Mean squares	
		Average daily gain	Average hay intake
Treatment	3	0.00106425***	1987.94***
1,2 Vs 3,4	1	0.00198025***	2221.24***
1,3 Vs 2,4	1	0.00112225***	3588.13***
Residual	12	0.00005325	99.79
Total	15	0.00025545	477.42

***P$\leq$0.001