# Water and mineral problems of the dromedary camel (an overview)

Farid M.F.A.

*in*

**Tisserand J.-L. (ed.).**
**Séminaire sur la digestion, la nutrition et l'alimentation du dromadaire**

**Zaragoza : CIHEAM**
**Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 2**

**1989**
pages 111-124

# Water and minerals problems of the dromedary Camel (an overview)

FARID, Mohamed F. A.
DESERT RESEARCH INSTITUTE
AL-MATAREYA, CAIRO, EGYPT

RESUME - «Métabolisme de l'eau et des minéraux chez le dromadaire». L'eau, la chaleur et les problèmes de sel qui s'ensuivent, peuvent être nuisibles à la survie des animaux du désert. De ce point de vue, la tolérance et l'adaptabilité du chameau dromadaire par rapport à ces trois problèmes a toujours été légendaire. Le but du présent article est de fournir en primer lieu une vue d'ensemble des problèmes du maintien de l'équilibre thermique et hydrique dans les conditions hostiles des environnements désertiques chauds. Plusieurs thèmes sont discutés, afin d'illustrer les particularités du chameau, y compris les avantages d'un grand corps, le rythme métabolique et la température du corps, le refroidissement par évaporation, les fonctions rénales, la conservation de l'eau et d'autres encore.

Une deuxième partie résume les résultats d'une série d'études comparatives entre les chameaux et les ovins, réalisées à l'Institut de Recherche sur le Désert en Egypte, en vue d'étudier quelques uns des facteurs affectant la consommation d'eau, l'excrétion et la conservation. Parmi ces facteurs (la privation d'eau, la salinité de l'eau, le type de diète et le niveau de consommation de protéines).

La dernière partie concerne ce qu'on appelle le problème du sel. Puisque les informations appropriées sont rares, seule une brève présentation est donnée des observations sur les besoins du chameau en sel, sur les problèmes de sel liés à une transpiration excessive, ainsi que sur la tolérance à l'eau salée en tant que boisson et l'effet de celle-ci.

Mots-clés: Dromadaire, métabolisme hydrique, thermo-régulation, bilan de NaCl.

*SUMMARY - Water, heat and the associated salt problems can be detrimental to survival of desert animals. In this respect, the dromedary camel has always been legendary for its tolerance and adaptation to conditions of physiological and nutritional stress. It is the purpose of this article to first give an overview of the problems of maintaining heat and water balance under the adverse conditions of hot dry desert environments. Several topics are discussed to illustrate the peculiarities of the camel including the questions about its capacity to store heat and water and the adaptive mechanisms involved.*

*A second section deals with a summary of some results from comparative studies between camels and sheep, carried out at The Desert Institute, Egypt, to investigate some of the factors affecting water intake, excretion and conservation. These include type of diet, level of protein intake, level salinity and water deprivation.*

*The last section considers the so called salt problem. Since appropriate information is scanty, only a brief account is given of the needs of camels in the desert for salt supplementation and its tolerance to drinking saline water.*

*Key words: Dromedary, water metabolism, thermo-regulation, NaCl balance.*

## Introduction

Desert inhabiting animals, the camel included, gain heat from both the warmer surrounding and from its own production of metabolic heat. Heat dissipation is a major problem in hot environments since conduction, convection and radiation may act to add to the heat load instead of being means of heat dissipation as they normally would in a cooler environment. Thus, animals have to depend on the water (expensive evaporative cooling). Therefore, heat and water balances of mammals inhabiting arid desert are inter-related. Their requirements for survival can be summed up as the need to achieve thermo-regulation and at the same time conserving water. The situation is particulary aggravated during hot dry summers where pasture plants dry up and water resources diminish.

It is the purpose of this article to examine situations where heat, water and salt could become problems to the dromedary camel in its natural habitat, and the peculiar adaptive characteristics of this unique animal enabling it to produce and reproduce under conditions not supportive of the mere survival of other domesticated desert ruminants. This is of great concern since what may seem a sign of inadaptability in some species may in fact be an adaptation or a mechanism of survival in the camel. Furthermore, many seemingly disadvantageous conditions could be of great benefit to the animal (FARID, 1987). The advantages to the camel of a fluctuating body temperature is a good example. This may be true to some extent in other species as well. In 1964, K. SCHMIDT-NIELSEN rightfully stated «Clearly, the rise of body temperature may have both advantages and disadvantages». At least it may be better to avoid classifying it as a failure of heat regulation.

## Maintaining heat and water balance. Basic principles

Since the Schmidt-Nielsens started their pioneer work on camel physiology in Algeria about 40 years ago, followed by Madamme Gauthier-Pilters in Algeria and Mauritania, Charnot in Morocco, MacFarlane in Australia and Kawashti in Egypt, many scientists engaged themselves in studying the camel and our state of knowledge has been advancing but in some aspects more than others. The subject of physiological adaptation of the camel has been frequently reviewed (e. g. SCHMIDT-NIELSEN, 1964; MACFARLANE, 1968b; GAUTHIER-PILTERS and DAGG, 1981; WILSON, 1984). It has been treated under two main headings: energy or heat balance and water balance. In order to avoid repetition, we prefer to get to the point by going back to its roots and try to answer the following questions: does the camel store heat?, does it store water?, and what adaptative mechanisms have given the camel its legendary reputation as the ship of the desert?

## Does the camel store heat?

### A. The fluctuating body temperature

The very wide range of diurnal temperature variation in camels was observed in Algeria by SERGENT and LHERITIER (1919) and the camel was erroneously associated with poor thermo-regulation capacity. SCHMIDT-NIELSEN et al. (1957), again in Algeria, observed an increase in the body temperature of camels during daytime of about 2 degrees C when water daily and up to 6 degrees C when water deprived in the summer (figure 1). They realized the significance of the fluctuating body temperature in relation to heat balance and water economy.

The increased body temperature during the day allows the camel to store heat gained from the hot environment and that produced from its metabolism. This heat is then lost passively during the cooler night by conduction, convection and radiation at no cost to body water. If body temperature has not risen during the daytime, heat would have been dissipated by the water expensive evaporative cooling mechanism. Moreover, the greater temperature rise in the water deprived camel enhances the efficiency of heat storage and water conservation. The higher body temperature also tends to decrease heat gain from the warmer environment which reduces the overall heat load on the animal. These explain the findings that camels have very low turnover rates of body water (MACFARLANE and HOWARD, 1974) and of rumen fluids (FARID et al., 1979), and its economic sweating apparatus (EL-ZEINY, WISAM, 1986).

The topic has not received due attention in other species. However, MACFARLANE (1968b) reported that sheep in a hot desert show a temperature rise during daytime of about 2 degrees C, from 39 to 41, where as the camel in the same environment went through a diurnal cycle from 37 to 40 degrees C, a rise of 3 degrees, as compared to the 6-degree cycle when deprived of free water intake (SCHMIDT-NIELSEN, 1964). Table 1 presents a comparison of the heat storage capacity of camels and sheep based on the above cited results and it clearly illustrates the advantages of the fluctuating body temperature and the larger body size of the camel.

### B. Body size and the metabolic rate

The camel benefits greatly from its diurnally fluctuating body temperature, being able to store heat during the hot daytime and loosing it passively during the cooler nights. This mechanism is further aided, to the benefit of the camel, by the advantages of its large body size and its low metabolic rate, both of which tend to decrease the overall heat load and conserve water from being lost through evaporative cooling.

**Table 1**

**HEAT STORAGE CAPACITY OF CAMELS AND SHEEP**

| ESPECIES | WEIGHT Kg. | TEMPERATURE RISE C. | HEAT STORAGE kcal/kg$^{0.75}$ |
|---|---|---|---|
| Camel: hydrated | 500 | 2 | 9.5 |
| water-deprived | 500 | 6 | 23.6 |
| Sheep | 50 | 2 | 5.3 |

Based on data from SCHMIDT-NIELSEN (1964) and MACFARLANE (1968b).

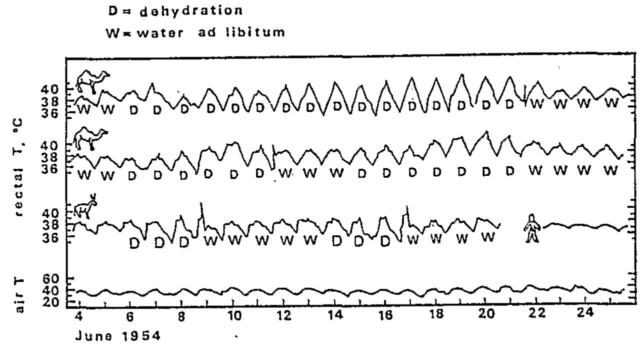


Figure 1. Diurnal temperature variations in camels, donkeys and man (after: SCHMIDT-NIELSEN et al., 1957).

Metabolic functions of animals are size dependant. They are universal exponential functions encompassing animals ranging in weight from the mouse to the elephant. There are three basic functions which we need to consider (BRODY, 1945; KLEIBER, 1961; MACFARLANE, 1968a,b): 1, metabolic rate is proportional to metabolic body size ($W^{0.75}$); 2, heat exchange with the surrounding environment is proportional to surface area ($W^{0.67}$), and 3, turnover rates of body water and the different parameters of water metabolism are proportional to body mass ($W^{0.82}$). All three exponents being less than 1.0 indicate that the larger animal with its relatively smaller surface area, metabolic size and body mass would be in a more favourable situation in the hot desert gaining less heat from the environment, producing less metabolic heat from within and evaporating less water to maintain thermo-regulation than the smaller-sized animal.

However, there are stricking deviations from these general functions between animals of similar weights but belonging to different species or to different breeds within a species (table 2), perhaps reflecting differences in adaptation to hot environments. In general, however, the camel is superior to the smaller sheep in agreement with the general functions cited above, and it is also superior to both Zebu and European cattle irrespective of the similar weight.

**Table 2**

**ENERGY METABOLISM AND WATER TURNOVER RATES OF CAMELS, CATTLE AND SHEEP**

| SPECIES/BREEDS | BODY WEIGHT kg. | ENERGY METABOLISM kcal/$kg^{0.75}$ | WATER METABOLISM ml/$kg^{0.82}$ |
|---|---|---|---|
| Camel | 400 | 50 | 104 |
| Cattle: B. taurus | 400 | 95 | 315-380 |
| B. indicus | | 80 | 260-350 |
| Sheep | 40 | 55-63 | 130-210 |

Source: MACFARLANE et al. (1968ab), MACFARLANE and HOWARD (1974).

On the other hand, the basal metabolic rate of camels is low, 50 kcal/$kg^{0.75}$, well bellow expected from the general relationship ($BMR = 70W^{0.75}$) and observed values for sheep and cattle (table 2).

Working in Australia, SCHMIDT-NIELSEN et al. (1967) found that $Q_{10}$ for camels was in the order of 2.0 or slightly higher not different from other animals. This tends to increase the basal metabolic rate when the body temperature rises, i. e. during the diurnal cycle. Nevertheless, this is counter-balanced by the camel's inherent low metabolic rate and the favourable effects of rising body temperature in reducing the flow of heat from the environment and in conserving water by decreasing the need for excessive evaporative cooling.

## C. Insulation

The capacity of the camel to fluctuate its body temperature diurnally, thus storing heat and conserving water, supplemented by the benefits of its large body size and low metabolic rate, is further aided by the insulating properties of its fur and skin. Therefore, insulation is an important topic to considerer as it relates to both energy balance and water balance of the camel.

WILSON (1984) summarized available information and stated that theoretical considerations suggest that desert animals exposed to high temperature and high levels of solar radiation should possess black skins to absorb much of the ultraviolet rays that penetrates the coat to prevent damage to tissues. The coat should be smooth and reflective, thick enough to act as a barrier against the environmental heat but not too thick that it may reduce evaporative heat loss at the skin surface.

If sweat evaporates at the skin surface and the coat remains dry, heat flow from the environment is reduced. On the other hand, if the coat is too thin such as in shorn animals, heat gain from the environment increases and more water would be used for evaporative cooling. Schmidt-Nielsen's experiments in the Algerian Sahara seem to indicate that fur thickness in the naturally shedding camel in the summer is most appropriate, about 30 mm. on the flanks and 15-20 mm. on the ventral surface of the body, SCHMIDT-NIELSEN (1964).

In addition to coat characteristics and skin colour, the thikness of the subcutaneous fat layer adversely affects heat flow to the surface of the skin. Perhaps the fact that fat in the camel is localized in the hump, as in the fat-tail and fat-rump in desert sheep, rather than being distributed subcutaneously is of value in heat dissipation.

## D. Evaporative cooling

Eventhough the advantages of large size, low metabolic rate and insultation reduce the overall heat load on the camel in its hot dry habitat, and the advantages of the fluctuating body temperature permitting some heat storage during daytime to be lost passively during the cooler night, the camel still needs to dissipate some heat in order to maintain thermo-regulation. In hot environments, this is achieved through the water (expensive evaporative cooling either from the respiratory tract by panting or through sweating and insensible evaporation from skin). For the purpose of heat dissipation it makes little difference where water is evaporated. The heat of vaporization of 1 g. water at 33 degrees C for example is 544 calories. In fact it may be greater than that if sweat evaporates at skin surface rather than at the tip of the hair, and SCHMIDT-NIELSEN (1964) suggested a value of 580 calories per 1 g. water.

Panting and the evaporation of water from the respiratory tract is of no value to the camel. Camels observed during the summer in the cool morning had a respiration rate of 6-11 respirations per minute. It increased to 8-18 respirations per minute in the hottest afternoon hours of the Sahara (SCHMIDT-NIELSEN, 1964) and to 20-24 respirations per minute in Australia (MACFARLANE, 1968a,b). In panting animals much higher rates were observed, e. g. 270 respirations per minute in sheep (BLIGH, 1959).

Camels, therefore, must depend on sweating. However, they have been thought for a long time to have no sweat glands (LEONARD, 1894; c.f. SCHMIDT-NIELSEN, 1964), but LEE and SCHMIDT-NIELSEN (1962) using tests with indicating paper revealed that sweat glands are distributed over the entire body surface of the camel. In a recent study in Egypt (EL-ZEINY, 1986), sweat glands from the hump, neck and flank regions were found tubular and moderately convoluted, intermediate in morphological structure between the eccrine and aprocrine types of man and cattle, respectively. Sweating rates ranged from 212 g. water/m²/hr. (40% of which insensible) in resting female camels to 293 g. water/m²/hr. after running in the sun for 30 minutes. Table 3 compares between sweating rates in camels and cattle, indicating the conservative evaporative cooling of the camel, especially since sweating in cattle represents only three-quarters of total evaporation under heat stress.

**Table 3**

**SWEATING RATES IN CAMELS AND CATTLE**

| SPECIES | SWEATING RATE g/m²/hr. | REFERENCE |
|---|---|---|
| Camels: | | |
| Algeria | 240 | SCHMIDT-NIELSEN, 1957 |
| Australia | 280 | MACFARLANE et al. 1963 |
| Egypt: resting | 212[1] | EL-ZEINY, 1986 |
| exercised | 293 | EL-ZEINY, 1986 |
| B. taurus | 580 (625)[2] | BROOK & SHORT, 1960 |
| Zebu cross | 329 (400) | FERGUSON & DOWLING, 1955 |

1. 60% sweat and 40% insensible loss.
2. Values between brackets represent total evaporation water loss, the difference being evaporation from the respiratory tract.

However, if sweating is essential to heat dissipation and survival in hot environments, it can also cause serious problems to the animal. Camels' sweat is rich in bicarbonates (pH 8.2-8.5) and is particularly high in potassium, 4 times as much as sodium (MACFARLANE et al., 1963). At high sweating rates, the amounts of urea, sodium, potassium and chloride eliminated in sweat are significant to be important in excretion and if overlooked it can upset results of nitrogen and minerals balances. In man at high sweating rates daily loss of sodium chloride may go up to 10-30 g. During sweating the effect of salt loss may not be apparent, but when water is replenished the body fluids become suddenly diluted and this may lead to serious consequences known as «heat cramps», sometimes ending in death.

It was noted, however, that the kidney can conserve sodium chloride (and urea) and reduce its excretion, but salt output from the skin cannot be similarly regulated even when the need for its conservation is at its greatest (SCHMIDT-NIELSEN, 1964).

## Does the camel store water?

In the past, people talked about camels storing water in specialized sacs in the bottom of their rumens. They also talked about storage of water in the hump, but later it was water derived from the oxidation of the fat in the hump. Now, we know for fact there are no such things as water stores neither in the rumen nor in the hump. As to the oxidation of fat stored in the hump, we should first realize that it is triggered by energy deficit and not by water deficit. Secondly, more water will be evaporated than the oxidation water formed (table 4), resulting in a net water deficit and, thus, it is actually to the disadvantage of the animal as far as water balance is concerned.

Neverthless, we shall still be asking the same question again: Does the camel store water?, and I am tempted to maintain the answer is YES!

**Table 4**

**WATER BALANCE FROM THE OXIDATION OF FAT AND STARCH**
**(Assumed metabolic level 10.0 Mcal.)**

| SUBSTRATE | AMOUNT USED kg. | WATER FORMED kg. | OXYGEN REQUIRED litres | WATER EVAPORATED kg. | NET WATER DEFICIT kg. |
|---|---|---|---|---|---|
| Fat | 1.0 | 1.07 | 2,010 | 1.69 | 0.62 |
| Starch | 1.0 | 0.56 | 820 | 0.71 | 0.15 |

After SCHMIDT-NIELSEN (1964).

It has been known for sometime that extracellular fluid volume of tropical ruminants expands in summer as a result of the effect of undernutrition and heat in relation to evaporative cooling (MACFARLANE, 1968a). This is controlled by osmoreceptors and volume receptors in the right atrial region, the information is integrated in the hypothalamus and the effector action takes place through hormones (ADH) and the kidney. This and the fact that camels, ruminants in general, have difficulty in putting on fat in hot dry environments explain why total body water constitutes more than 70% of live body weight, but may go down to about 50% in cooler environments with more favourable and better nutritious conditions. Furthermore, PECK (1939, c. f. SCHMIDT-NIELSEN, 1964) suggested that a «physiological subcutaneous edema» occurs in malnourished camels on high salt intake starting within few hours after watering and lasting about 24 hours. SCHMIDT-NIELSEN (1964) had seen no evidence of it. However, we have seen it once last year, evident to the naked eye, in one female camel drinking dilute sea water, 13,000 ppm. total salinity (FARID, SHAWKET and ABOU EL-NASR, unpublished).

In addition, water is also stored, in a sense, as fluid in the rumen-reticulum which may constitute up to 15% of the live body weight of the animal. This stored water can be drawn upon at times of need such as under conditions of water deprivation, 12 days in camels and 3 days in sheep (FARID et al., 1979). Camels were more economic than sheep (figure 2), and after 12 days without water they still had water in the rumen, ml/kg$^{0.82}$, about equal to what the sheep had after only three days without water. Therefore, it appears that ruminants in hot dry environments are in fact capable of temporarily storing water in their expanded extracellular fluid compartment and in the rumen. In this respect, camels prove once more its supperiority over other domesticated desert ruminants.

## The legendary camel and its adaptive mechanisms for water conservation

The shortage of water is not a problem itself even in a hot desert environment. It is only so when available resources fail to replenish mandatory water losses and after possible physiological adjustments were effected. There appear to be limits to such adjustments, however, beyond which water balance is upset. The minimum quantity of water used for sweating is dictated by the need for heat dissipation. Similarly, the minimum quantity of water excreted in urine is dictated by the amount of excretory products, mainly sodium chloride and urea, and the kidney's concentrating capacity.

Species differ in their capacity to adjust. MACFARLANE (1968b) stated «The camel is a class apart not only in having a low rate of water use, but also in readily restricting water losses by kidney or gut as soon as there is any reduction in water intake».

### A. Water content, distribution and turnover

The camel, as well as other ruminants, contains water in about two-thirds of their live body weight. In general, animals in hot dry environments have more total body water (TBW) than those in wet tropics and the temperare zones, over 70% vs. 52% (MACFARLANE, 1968a,b). This is partly because of the difficulty of laying down fat and partly because of their expanded volume of gut contents, primarily the rumen-reticulum. In addition, it has been reported that the extracellular fluid (ECF) compartment expands by heat and under-nutrition. This is considered advantageous under conditions of shortage of water (MACFARLANE, 1968b; WILSON, 1984) as it may act as a water conserving mechanism.

Total body water of camels in the hot dry environment of Ogaden, Somalia, and in Australia was estimated at 72-74% of live body weight (MACFARLANE and HOWARD, 1974). In Australia after a 10 year drought broke and the animals put on fat, their TBW was only 52% of live weight although the absolute total water content was nearly the same.

The distribution of TBW, percent of live weight, in camels and sheep is presented in Table 5. Differences between the two species were small and were not different from the average figures cited by WILSON (1984) for the fully hydrated camel:

| Compartment | % of live weight |
|---|---|
| Total body water | 65 |
| Fluids of the alimentary canal | 12 |
| Intra-cellular water | 34 |
| Interstitial water | 14 |
| Plasma | 5 |

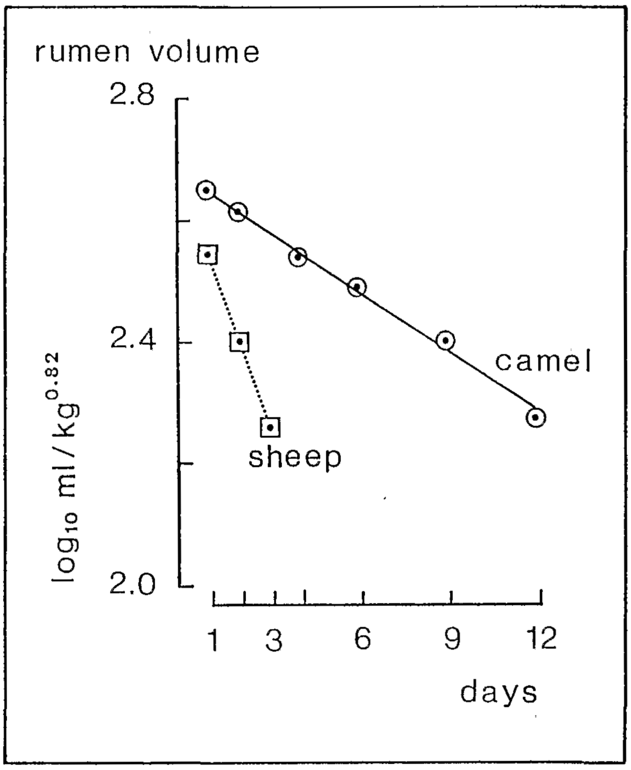


Figure 2. Changes in rumen fluid volume associated with water deprivation in camels and sheep (after FARID et al., 1979).
Regression equations:
1. Camels: Y = 2.683 — 0.0334(X) (r = 0.951**)
2. Sheep: Y = 2.675 — 0.1370(X) (r = 0.981**)

Water turnover is the amount of water passing through an animal in a unit time. Its main determinant is the rate of water loss from the animal. When the TOH dilution technique is used, both turnover rate of TBW and its biological half-life are estimated. MACFARLANE (1968a) indicated that there are considerable genetic as well as environmental differences (figure 3). Dry camels used less than half as much water as the dry cow and Merino sheep were intermediate. Lactating camels used 50% more after than non-lactating ones. Sheep grazing salt bush used more water for diluting salt in the urine than desert Merinos used for evaporative cooling. Finally, Bos indicus cattle used less water than their B. taurus mates. However, some of these observed genetic differences in water use and turnover rates (ml/kg/24 hr) tended to narrow when expressed per unit body mass (ml/kg$^{0.82}$/24 hr) as shown in table 6. Nevertheless, the superiority of the camel was still evident.

**Table 5**

**THE DISTRIBUTION OF TOTAL BODY WATER IN CAMELS AND SHEEP**

| | CAMELS | | SHEEP | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Body weight, Kg. | 288 | 337 | 50.3 | 37.8 |
| Body solids, % | 43.9 | 30.8 | | 33.9 |
| Total body water, % | 65.1 | 69.2 | | 66.1 |
| Plasma volume | 4.7 | 5.3 | 6.3 | 4.7 |
| Interstitial water | 14.5 | 13.9 | 20.1 | 18.8 |
| Intra-cellular water | | 38.0 | | 42.5 |
| Gut water ....... | | 12.0 | | 10.0 |

1. SCHMIDT-NIELSEN (1964), Algerian Sahara.
2. MACFARLANE et al. (1963), Australia.
3. MACFARLANE et al. (1956), Merino, Australia.
4. PUROHIT (1979), Marwari sheep, India.

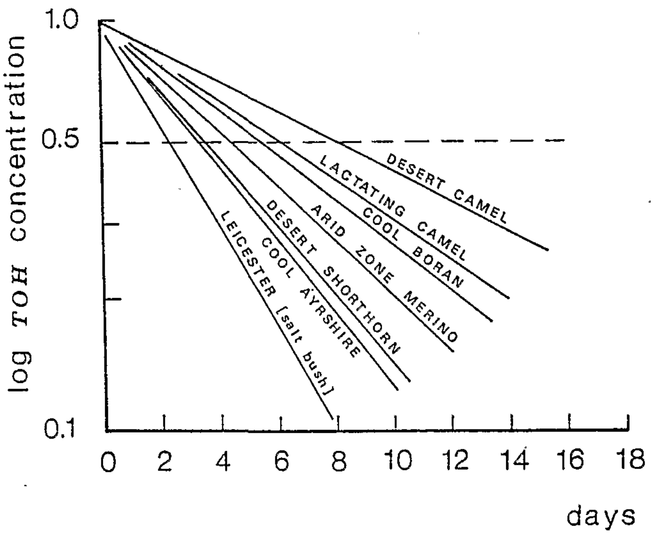


Figure 3. Water turnover rates in ruminants (after MACFARLANE, 1968a).

## B. Kidney function and the control of urine flow

Animals lose water in urine, in faeces and by evaporation. The evaporative water loss is dictated by the need for heat dissipation as discussed earlier. However, the camel appears to have some indirect control over it especially under adverse conditions through its fluctuating body temperature and by sweating instead of panting which conserves both water an energy.

**Table 6**

**WATER CONTENT AND WATER TURNOVER RATES OF CAMELS AND RUMINANTS AT PASTURE**

| ANIMAL SPECIES | WEIGHT kg. | TBW % | TURNOVER kg. | ml/24 hr kg$^{.82}$ |
|---|---|---|---|---|
| [1] Camel, Australian | 565 | 68 | 33 | 104 |
| Sheep, Merino | 44 | 54 | 86 | 168 |
| Cattle, Shorthorn | 332 | 65 | 102 | 291 |
| [2] Camel, Somali | 520 | 70 | 61 | 188 |
| Goat, Somali | 40 | 69 | 96 | 185 |
| Sheep, Ogaden/Somali | 31 | 68 | 107 | 197 |
| Cattle, Boran | 197 | 77 | 135 | 347 |

Source: MACFARLANE and HOWARD (1974)

1. Australia, Adelaide summer drought pasture.
2. Kenya and Somalia, Equatorial desert pasture.

Urine is usually the second major avenue of water loss in animals. The kidneys of animals adapted to hot dry environments contain longer loops of Henle than animals in cool or wet environments, and the more longer loops of Henle there are in the kidney medulla the higher is the possible urine concentration through the counter-current concentrating mechanism (GOTTSCHALK and MYLLE, 1959). The ratio of the thickness of the medulla to cortex is a good index of the potential water reabsorption capacity (SPERBER, 1944; ABDALLA and ABDALLA, 1979). These anatomical features are associated with the kidney's capacity to control water loss by concentrating the urine and by reducing its rate of flow.

| | URINE WATER ml/day/kg$^{0.82}$ | URINE SOLIDS DM% |
|---|---|---|
| Camel: fresh | 10.5 | 9.81 |
| saline | 21.9 | 7.27 |
| Sheep: fresh | 23.5 | 6.32 |
| saline | 52.0 | 5.12 |

Camels and sheep and abundance of long loops of Henle, but cattle have short loops and short papillae.

MACFARLANE (1968b) claimed that the sheep's kidney has a slightly greater capacity to concentrate urine than that of the camel. Maximum concentrations observed during water deprivation in the summer were 3.5-3.8 osmoles in sheep, 3.1 osmoles in camels and 2.6 osmoles in cattle. He concluded that the reduction in urine flow is, therefore, more important for water conservation in the camel than urine concentration. However, in camels and sheep drinking fresh or dilute sea water, about 13000 ppm. total salinity camels urine was more concentrated than that of sheep irrespective of water salinity of urine flow (FARID, SHAWKET and ABOU EL-NASR, unpublished):

The kidney of the camel would be expected to be more responsive to vasopressin in the reduction of urine flow. At a urine flow rate os 5 ml/1min., the administration of 1 mU of vasopressin intravenously into a 400 kg. camel, equivalent to 2.5 uU/kg or 0,06 uU/ml extracellular fluid, the flow rate was lowered to 3 ml/min. Relative to camels, sheep and cattle would require twice and ten times as much vasopressin to give a detectable response (MACFARLANE et al, 1967).

During dehydration, vasopressin inhibits urine flow in the kidney (SIEBERT and MACFARLANE, 1971). Particularly high levels of vasopressin in the plasma, up to 20 to 100 uU/ml., were recorded in ruminants exposed to hot dry environments and deprived of water. These higher levels increase potassium secretion up to ten times more than the resting level, and sodium to a lesser extent, and this is accompanied by an increase in the rate of excretion of water by osmotic diuresis (MACFARLANE, 1968b).

Another way of reducing urine flow is the reduction of glomerular filtration rate. In camels it is normally around 55-65 ml/100 kg/min. and it is reduced to 15 ml/100 kg/min. after 10 days of water deprivation. In sheep and cattle normal filtration is 90-150 ml/100 kg/min. and it falls in dehydrated animals to one-third. Vasopressin does not reduce filtration to this extent (MACFARLANE et at., 1968b) so that some other mechanism is involved, probably circulatory.

## C. Faecal water

The amount of faeces eliminated and its water content are dependant on the type of feed and its digestibility, i. e. the output of the undigested matter. When fed similar diets camels excrete less water in the faeces per 100 g. faecal DM than other ruminants. Typical values of camels range between 109 and 268 g water/100 g faecal DM (CHARNOT, 1960; SCHMIDT-NIELSEN, 1964) as compared to 566 g. water /100 g. faecal in grazing cows.

Water reabsorption takes place along the alimentary canal but final conservation is in the colon where sodium reabsorption results in the return of water to the blood. MACFARLANE (1968b) indicated that cattle normally excrete faeces with 80% water in it, but after 3 days without water it falls to about 65%. Bos indicus cattle reduce faecal water output by about 10% more than B. taurus. Sheep on dry summer pastures produce pellets containing about 60% water, falling to 45% after 5 days water deprivation. Camels, on the other hand, produce faeces containing 38% water after 10 days of water deprivation. Table 7 summarizes a comparison between camels, sheep and cattle in terms of survival without water in a desert environment (40 degrees C max. temperature) in relation to weight loss and some parameters of water metabolism and conservation. It is shown clearly that camels outperform desert Merino sheep, and cattle comming last. In general, camels at one end of the scale and B. taurus cattle at the other are the two extremes of the range of adaptation and survival under the adverse conditions of hot dry desert environments.

**Table 7**

**SURVIVAL OF RUMINANTS WITHOUT WATER IN HOT DRY DESERT ENVIRONMENTS (40 degrees C max. t.)**

| PHENOMENA | CAMELS | DESERT MERINO | SHORTHORN CATTLE |
|---|---|---|---|
| Days survival at 40 C | 12-15 | 6-8 | 3-4 |
| Weight loss, % per day | 2.0 | 4.5 | 7.0 |
| Water loss, % of wt. lost | 85 | 74 | 66 |
| Loss of plasma, % | 4.5 | 8.0 | 10.0 |
| Max urine concentration, Osm. | 3.1 | 3.8 | 2.6 |
| Max faeces dehydration, % water | 38 | 45 | 60 |
| Max plasma Na, mEq/l | 202 | 185 | 170 |

Source: MACFARLANE et al. (1968b).

## D. Tolerance to dehydration. Where water is lost from?

During hot dry summers, nomadic pastoralists take their flocks ion grazing circles between water holes. Under these conditions and especially in mixed herds, physiological differences between species show up clearly. MACFARLANE et al. (1956, 1961, 1963) experimented with the effects of water deprivation in camels, Merino sheep and Shorthorn cattle. Figure 4 summarizes data on 20% body weight loss in these three species kept without water in relation to mean maximum ambient temperature. Evaporation water loss increased as the ambient temperature rose. A 20% loss of body weight occured in 7 to 10 days in camels, 4 to 5 days in sheep and 2 to 3 days in cattle when the mean maximum temperature was above 40 degrees C, corresponding average daily water losses were 2% in camels, 4-5% in sheep and 8% in cattle. Cattle and sheep ceased to eat on the second or third day of water deprivation but camels continued up to the fifth day and beyond at mean maximum temperature above 40 degrees C, longer at lower temperatures. Death from the loss of 28-32% of body weight occured in about 15 days in camels, 7 days in sheep and 4 days in cattle.

Urine flow is normally high in cattle, about 30 ml/min., and it decreased to 5 ml/min. by the third day of water deprivation. In sheep it was initially 2 ml/min., fell to 1 ml/min. by the third day, then to 0.2-0.4 ml/min. on the sixth day. Camels, on the other hand, excreted urine at the rate of 4-5 ml/min. when fully hydrated, but after only one day of water deprivation urine flow dropped sharply to 2 ml/min., and it was maintained at a rate of 1-2 ml/min. up to the tenth day. This most rapid reduction in the rate of urine flow of camels immediately after the onset of water deprivation appears to be related to its capacity to resist dehydration. Sheep and cattle breeds indigenous to desert habitats share this characteristic with the camel to some extent. The maximum concentration of urine was reached on the second or third day of water deprivation then fell as there were less electrolytes to be excreted.

Faecal water loss was higher in cattle than in camels and sheep. Under conditions of water deprivation, camels could excrete relatively dry faeces containing only 38% water after 10-15 days, sheep 45% after 6-8 days and cattle 60% after 3-4 days (table 7).

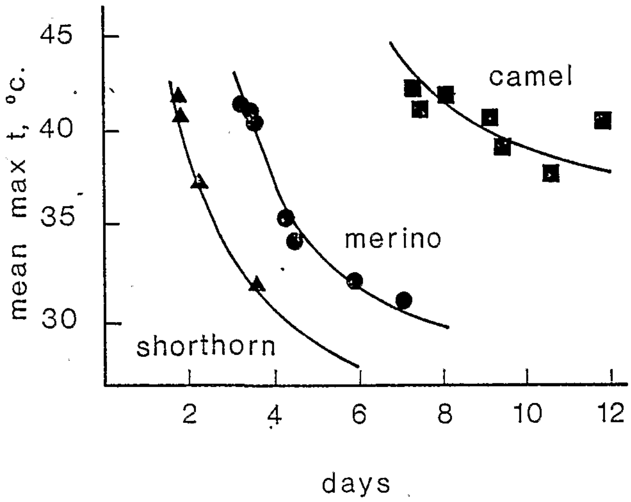


Figure 4. Twenty percent weight loss in summer in relation to mean maximum temperature (after: MACFARLANE, 1968b).

It therefore appears that the kidneys and colon of camels reduce the water output more rapidly and more completely than in sheep, and sheep more than cattle.

The most important determinant of the animal's capacity to withstand dehydration is the source of water used for evaporative cooling and that excreted in faeces and urine, and it was found to differ between species. Table 8 summarizes some of the available information from camels and sheep, and the stricking differences between the two animals are clearly evident. In the camel only 2.5-5.5% of the water loss comes from plasma, about one-third that in sheep where plasma contributed 13% of the total water lost. In both species plasma contributed the least to total water loss. The interstitial fluid contributed 41% in sheep and only 10-32% in camels. Therefore, while the extracellular fluid contributed less the one-third of the total water loss in camels, range 15 to 35 percent, it contributed more than half in sheep, about 54%. On the other hand, intracellular and gut fluids contributed 65-85% of the total water lost from the camel but only 46% in sheep.

The percentage decrease in the volume of each fluid compartment was also evaluated. Schmidt-Nielsen (1964) showed that the greatest proportional loss occured in the interstitial fluid and it was about 38%, where as the intracellular fluid had been reduced by 24%. The smallest relative water loss occured in plasma volume with less than 10% reduction. The experiment by Macfarlane et al. (1963), on the other hand, indicated that the greatest proportional loss ocurred in the intracellular and gut fluids which were reduced by one-third. Loss in the SCN space amounted to 16% and that in plasma was 21%. In sheep, on the other hand (MACFARLANE et al., 1956), all plasma, interstitial and the extracellular spaces suffered much greater losses than in the camel amounting to 45% of the three spaces after five days without water. Only 28% of the intracellular and gut fluids were lost. Cattle are similar to sheep, also drawing upon the extracellular fluid, particularly plasma (MACFARLANE, 1968b).

**Table 8**

**SOURCES AND DISTRIBUTION OF WATER LOST DURING DEHYDRATION FROM CAMELS AND SHEEP**

| | CAMELS (1) | CAMELS (2) | SHEEP (3) |
|---|---|---|---|
| Days without water | 9 | 8 | 5 |
| Initial weight, kg. | 337 | 288 | 50.3 |
| Total water loss, kg. | 66 | 49 | 11.8 |
| % of weight | 19.6 | 17.0 | 23.5 |
| Source of water lost, % of total: | | | |
| plasma | 5,5 | 2.4 | 12.7 |
| interstitial | 9.7 | 32.2 | 40.9 |
| SCN space | 15.2 | 34.6 | 53.6 |
| intracelular | 31.1 | (65.3) | (46.4) |
| alimentary canal | 54.5 | | |
| Percent of space lost: | | | |
| plasma | 20.6 | 8.8 | 45 |
| intracellular | 14.3 | 37.8 | 45 |
| SCN space | 15.6 | 31.0 | 45 |
| intracellular and alimentary | 33.3 | 24.2 | 28 |

(1) MACFARLANE et al. (1963).
(2) SCHMIDT-NIELSEN (1964).
(3) MACFARLANE et al. (1956).

Camels have thick capillary walls which help retain a high concentration of albumin in plasma (MACFARLANE, 1968b). The albumin in plasma increase its osmotic pressure which is instrumental in holding fluid in the vascular space, even drawing it from the gut, and circulation can thus be maintained (Wilson, 1984). Dehydrated sheep (and cattle) was indicated to lose up to 45% of their plasma volume whereas in camels it was only 9-20% (Table 8). The albumin concentration in plasma was higher in camels than in cattle (Table 9), and after 3 days without water in cattle and 10 days in camels it increased 17 and 54 percent, respectively. Total plasma proteins and globulin also increased. As the plasma proteins became more concentrated in the camel their plasma volume was better sustained.

**Table 9**

**EFFECT OF WATER DEPRIVATION ON THE CONCENTRATIONS (g./100 ml.) OF PLASMA PROTEINS IN CAMELS AND CATTLE**

| SPECIES | DAYS WITHOUT WATER | TOTAL PLASMA PROTEINS | ALBUMIN | GLOBULIN |
|---|---|---|---|---|
| Camels | 0 | 5.0 | 3.5 | 1.5 |
| | 10 | 8.6 | 5.4 | 3.2 |
| Cattle | 0 | 7.3 | 3.5 | 3.8 |
| | 3 | 9.4 | 4.1 | 5.3 |

Source: MACFARLANE (1968b).

In conclusion, the essential differences between camels on one hand and cattle and sheep on the other in desert survival are derived from their capacity to temporarily store heat and water and their efficient water conservation mechanisms and the maintenance of circulation.

## Water intake and excretion in relation to some dietary factors and water deprivation

Until recently, our knowledge about the nutrition and feeding of camels was restricted to some field observations on the range, reviewed by Newman (1979), and suggestions for the supplementation of work and military pack camels based on those of Leese (1927) and Acland (1932). With regard to possible nutrition-environment interactions, our group has been engaged over the past decade in investigating some of the nutritional characteristics of the camel especially those related to stressful conditions prevailing in its natural habitat and possibly affecting its basic adaptive mechanisms outlined in the preceeding section (e.g. SHAWKET, 1976; FARID et al., 1979; SOOUD, 1980; KANDIL, 1984; ABOU-EL-NASR, 1985; KANDIL et al., 1985; FARID et al., 1985 a, 1985b; FARID, 1987). Some of these conditions are the progressive decrease of dietary energy density and of the protein content in the drying up pasture as the dry season advances, and the need to water the animals intermittently because of diminishing water resources and sometimes deliberately to expand the grazing grounds.

The following discussion shall concentrate upon the effects of type of diet, level of protein intake and water deprivation on water intake and excretion in camels and excretion in camels and sheep. Results from three experiments pertainning to the subject are presented in part in Tables 10,11 and 12 (FARID, et al., 1985 b). It is noteworthy to mention, however, that these experiments were carried out with the animals kept in shaded pens and were not, therefore, heat stressed which need to be investigated in future experiments.

In these experiments, were adopted, those for cattle were applied to camels. In the first experiment —effect of type of diet (table 10)— both camels and sheep received 100 and 125 percent of their estimated TDN and DCP requirements for maintenance, respectively, and watered free choice once daily. Two rations were used with estimated energy concentration of 1.8 and 2.6 Mcal ME/kg DM, containing 93 and 45 percent roughage on TDN basis, In the second experiment —effect of level of protein intake (table 11) —both sheep and camels were given mixed roughage and concentrate diets supplying 125 or 75 percent of their DCP requirements for maintenance and 100 percent of the TDN requirements, and the animals were watered once daily throughout. In the water deprivation experiment —experiment 3 (table 12)— both camels and sheep were fed a low protein all roughage diet consisting of 7 parts wheat straw and 3 parts berseem hay, the mixture containing 1.2 per cent nitrogen on dry matter basis. The diets were offered in amounts to satisfy 100 and 50 percent of the calculated TDN and DCP requirements for maintenance, respectively. They were watered either once daily or intermittently every three days in sheep and every 12 days in camels.

The results presented in tables 10 and 11 indicated that irrespective of dietary treatments camels needed about 40 to 60 percent less water then sheep whether expressed per unit

**Table 10**

**EFFECTS OF TYPE OF DIET ON WATER INTAKE AND EXCRETION IN CAMELS AND SHEEP**

| Animal species<br>Type of diet | CAMELS<br>HR | <br>LR | SHEEP<br>HR | <br>LR |
|---|---|---|---|---|
| Energy density, Mcal ME/kg DM | 2.09 | 2.44 | 1.75 | 2.49 |
| Energy intake, g TDN/kg $^{0.75}$ | 27.30 | 31.30 | 28.90 | 29.80 |
| Protein intake, g DCP/kg $^{0.75}$ | 3.42 | 2.85 | 4.05 | 3.49 |
| Free water intake, ml/g DMI | 2.03 | 1.46 | 2.47 | 2.58 |
| ml/kg $^{0.82}$ | 54.80 | 38.50 | 108.10 | 83.40 |
| Total water intake, ml/kg $^{0.82}$ | 66.60 | 51.40 | 124.90 | 99.60 |
| Faecal water, ml/kg $^{0.82}$ | 26.10 | 12.60 | 36.70 | 15.80 |
| Urinary water, ml/kg $^{0.82}$ | 17.90 | 10.40 | 52.80 | 38.60 |
| Evaporation loss, ml/kg $^{0.82}$ | 22.60 | 28.40 | 35.40 | 45.20 |

Source: FARID et al. (1985b).

dry matter intake or per unit body mass (Kg 0.82). Sheep needed water in proportion to dry matter intake when fed diets sufficient in both energy and protein but with different energy densities. Camels under similar treatments decreased their free water intake as the roughage portion in the diet decreased. Both camels and sheep needed less free water as the level of protein intake decreased (table 11), and when they were watered intermittently, every three days in sheep or 12 days in camels.

**Table 11**

**EFFECTS OF LEVEL OF PROTEIN INTAKE ON WATER INTAKE AND EXCRETION IN CAMELS AND SHEEP**

| Animal species<br>Level of protein intake | CAMELS<br>HP | <br>LP | SHEEP<br>HP | <br>LP |
|---|---|---|---|---|
| Energy density, Mcal ME/kg DM | 2.50 | 2.20 | 2.30 | 1.90 |
| Energy intake, g TDN/kg $^{0.75}$ | 32.50 | 21.80 | 26.50 | 23.50 |
| Protein intake, g DCP/kg $^{0.75}$ | 2.60 | 1.30 | 2.71 | 1.51 |
| Free water intake, ml/g DMI | 2.16 | 1.38 | 2.39 | 1.62 |
| ml/kg $^{0.82}$ | 57.70 | 28.00 | 90.30 | 53.90 |
| Total water intake, ml/kg $^{0.82}$ | 71.00 | 37.00 | 104.80 | 66.80 |
| Faecal water, ml/kg $^{0.82}$ | 12.70 | 9.70 | 14.40 | 11.40 |
| Urinary water, ml/kg $^{0.82}$ | 7.30 | 7.00 | 39.90 | 19.90 |
| Evaporation water, ml/kg $^{0.82}$ | 51.00 | 20.30 | 50.50 | 35.50 |

Source: Farid et al. (1985b).

**Table 12**

**EFFECTS OF WATER DEPRIVATION ON WATER INTAKE AND EXCRETION IN CAMELS AND SEEHP FED A LOW PROTEIN ALL ROUGHAGE DIET**

| Animal species<br>Watering frequency (days) | CAMELS<br>1 | <br>12 | SHEEP<br>1 | <br>3 |
|---|---|---|---|---|
| Energy density, Mcal ME/kg DM | 2.00 | 1.88 | 1.96 | 1.98 |
| Energy intake, g TDN/kg $^{0.73}$ | 17.90 | 15.60 | 17.50 | 23.60 |
| Protein intake, g DCP/kg $^{0.73}$ | 0.38 | 0.94 | 1.42 | 1.91 |
| Free water intake, ml/g DMI | 2.29 | 1.68 | 4.24 | 2.38 |
| ml/kg $^{0.82}$ | 52.60 | 36.30 | 90.00 | 85.20 |
| Total water intake, ml/kg$^{0.82}$ | 61.20 | 43.90 | 100.00 | 98.90 |
| Faecal water, ml/kg$^{0.82}$ | 23.20 | 10.10 | 21.10 | 17.10 |
| Urinary water, ml/kg$^{0.82}$ | 12.30 | 11.60 | 47.30 | 46.90 |
| Evaporation water, ml/kg$^{0.82}$ | 25.70 | 22.20 | 31.60 | 34.90 |

Source: Farid et al. (1985b).

Expressed per unit body mass, camels consistently lost less water in faeces and urine than sheep when fed diets differing in energy concentration or in protein content, or when water deprived. Differences between species in faecal water excretion were less in magnitude when fed the low roughage diet, i.e. the diet higher in energy density. Irrespective of treatments, urinary water losses in camels were less than or equal to faecal water output. In sheep, on the other hand, it was two to three times as much as faecal water irrespective of treatments (Tables 10 and 11). Both faecal and urinary water excretion in both species decreased as the energy concentration of the diet increased and as the level of protein intake decreased, possibly a reflection of the effects of these treaments on free water intake as pointed out earlier.

During water deprivation the superiority of the camel was clearly evident (Table 12). Water conservation was attained mainly through the reduction of faecal water excretion which decreased to about 44 and 81 percent of the rate of faecal water excretion in hydrated camels and sheep, respectively. Urinary water excretion, on the other hand, was hardly affected during dehydration in either camels or sheep. Regulation of faecal water output takes place at two sites, the rumen-reticulum and the hind-gut. It is beleived to provide water to balance, at least partly, the losses from plasma and the extracellular fluids incurred during dehydration.

In conclusion, the above cited results indicated that the camel is a better adapted animal than sheep to arid conditions being more economic in its needs for water and in its use of water under a variety of nutritional (and physiological) stresses. With the advent of the dry season, the energy density of the camel's diet in its natural habitat will decrease and, consequently, both free water intake and water excretion will be expected to increase, and one would expect the camel to be at a disadvantage. However, this is counter-balanced by the simultaneous decrease of the protein content of the diet which help reduce the camels need for drinking water and reduces water excretion as well. In addition, both decreased energy density and protein content will affect dry matter intake, reducing the metabolic heat load and further reducing the animal's need for free drinking water. In this situation, the animal is further aided by water deprivation which also, and possibly more important, improves the efficiency of utilization of both energy and nitrogen.

## The minerals problems, with emphasis on water salinity

Only meagre information is available on the subject, and the following introductory discussion shall depend primarily on information supplied in two recent books by GAUTHIER-PILTERS and DAGG (1981) and WILSON (1984). Camels were known for sometime to prefer grazing and browsing salty plants, the halophytes, especially the fleshy species, generally characterized with higher protein and low fibre contents and have the advantage of remaining green during the dry summer. Halophytes may contribute up to one-third of the total diet selected and consumed by the camel. Some of the most preferred species are Atriplex, Nucularia and Traganum. The list also include Anabasis, Arthrocnemum, Halocnemum, Haloxylon, Cornulaca, Suaeda, Tamarix and many others.

The need of camels for salt was known to nomadic pastoralists and the so called «salt cure» practiced in different forms: seasonal or rotational visits to known wells with saline water, to places with salt earths or to areas with dominant halophytic plant associations. In Tunisia for example, camels graze halophytes in salty depressions for up to 8 or 9 months every year and depending on well water containing around 3500 ppm total salinity. The rest of the year is spent in rocky grazing grounds and the well water contains around 500 ppm total salinity.

Periodic salt cure is also practiced in many areas. In Mauritania and in other places as well, areas where rain water washes salty earths into depressions are visited periodically or on traditional migration routes to water the camels from saline wells and to collect the drying up salty crust. This would be offered to the camels (about 2 kg for 7 camels every 15 to 20 days). In Tebesti, Chad, on the other hand, camels are taken to salty grounds twice a year, just before and just after the rainy season. Camels would then feed on halophytes, drink saline water and the crust is made use of.

Salt supplementation has also been known for centuries. Reports indicate that in salt caravans south of the Sahara, where salt was sometimes traded for gold weight for weight in the twelfth century, a camel would carry four slabs of salt weighing 30 to 35 kg each, three for trade and one for the camel. The salt cure practice is a practical way of periodically supplementing camels with salt, not only sodium chloride but also other major and trace elements as well. Although this may not be as effective as regular supplementation practiced on farms, it appears very successful under nomadic grazing systems prevaling in arid zones.

In addressing the problems of salt (minerals) deficiency in camels WILSON (1984), based on blood analysis, stated «There is little to show that the mineral and vitamin requirements are different in camels from those of other animals. ...For practical purposes, normal feeding will insure adequate levels of minerals and vitamins except where known deficiencies or imbalances occur.» However, he also stated that «The apparent requirements for salt by camels, for maintenance alone, are between 6 to 8 times those normally considered adequate for other livestock». Contrasting the two statements, and considering the fragmentary information we have available, see below, we believe the latter statement is probably the more correct, at least with respect to sodium chloride.

Disorders of mineral deficiencies or excesses in camels in its natural habitat did not receive due consideration yet. However, several types are known in relation to sodium chloride deficiency and to the imbalance of the calcium/phosphorus ratio. Cutaneous necrosis is a well known syndrome of sodium deficiency and it is treated with high levels of sodium chloride supplements, up to 140 g./day. A certain nervous syndrome affecting camels is beleived to result from chronic prolonged salt starvation. In addition, cramps also occur in camels as in man if salt lost in sweat is not replaced. In addition to sodium chloride deficiency, the disease known as «krafft» is associated with imbalanced Ca/P ratio. This is of particular importance since some of the most preferred grazing and browsing plants, belonging to the families Capparidaceae and Zygophyllaceae, have a distorted Ca/P ratio of 11:1 or wider. Other plants such as saltbush and legumes are somewhat more balanced with a 5:1 ratio.

Therefore, salt and phosphorus supplementation are prerequisites of better production. Suggested salt allowances under normal arid zone conditions range between 30 and 60 g./day. However, it has been reported that a healthy camel grazing saltbush may still consume 120 g. salt daily when freely offered. An allowance of 140 g./day was found to improve cases of skin necrosis and lameness in the dromedary.

The salinity of the drinking water is another subject to consider. As indicated above, one form of the traditional salt cure practice is the periodic visits to known wells with salty waters. MALOIY (1972, c. f. WILSON, 1984) reported that camels can tolerate water containing 5.5% salt for some days. Lesser concentrations increased feed intake, but also increased water intake and water excretion in the urine.

**Table 13**

**EFFECTS OF SODIUM CHLORIDE CONCENTRATION IN THE DRINKING WATER ON BODY WEIGHT CHANGES, WATER INTAKE AND EXCRETION AND NUTRIENTS DIGESTIBILITIES**

| ITEMS | TAP WATER | 1.0% NaCl | 1.5% NaCl | 2.0% NaCl | +S.E. |
|---|---|---|---|---|---|
| Number of animals | 3 | 3 | 3 | 3 | |
| Initial weight, kg | 319 | 340 | 321 | 324 | 17.01 |
| Weight change, g./day | 250 | 286 | 286 | 262 | 9.34 |
| Free water intake: | | | | | |
| ml./kg $^{0.82}$ | 92 | 153 | 159 | 119 | 9.58 |
| ml./g. DMI | 2.52 | 3.88 | 4.34 | 3.43 | 0.24 |
| Faecal water, ml/kg $^{0.82}$ | 25 | 28 | 34 | 24 | 1.30 |
| Urine water, ml./kg $^{0.82}$ | 32 | 56 | 68 | 51 | 4.58 |
| DM intake, g./kg $^{0.75}$ | 55 | 60 | 55 | 52 | 0.83 |
| Digesibilities, % | | | | | |
| dry matter | 64.5 | 64.5 | 58.9 | 58.4 | 0.89 |
| crude protein | 53.9 | 54.7 | 52.8 | 52.6 | 0.34 |
| crude fibres | 64.2 | 66.3 | 64.0 | 62.5 | 0.50 |
| ether extract | 48.0 | 48.0 | 48.1 | 48.5 | 0.20 |
| N-free extract | 68.9 | 66.8 | 58.8 | 58.6 | 1.51 |
| TDN intake. g./kg $^{0.75}$ | 31.1 | 33.9 | 29.2 | 27.4 | 0.77 |
| DCP intake, g./kg $^{0.75}$ | 3.70 | 4.10 | 3.66 | 3.46 | 0.07 |

Source: KANDIL et al. (1985).

Information on long-term salt tolerance and effects were still wanting. Our group (KANDIL et al., 1985) carried out a study to investigate the effects of drinking saline water with varied sodium chloride concentrations on feed utilization and nitrogen and mineral balances (Tables 13 and 14).

Twelve female camels in four groups were offered to drink fresh tap water or 1.0, 1.5 or 2.0 percent sodium chloride solutions in the tap water. All animals were fed berseem hay ad libitum for the duration of the experiment which lasted 120 days. At the end, a six-day digestion and balance trial was carried out and blood was sampled for sodium and potassium determinations in the serum. Live body weights were recorded weekly throughout.

**Table 14**

**EFFECTS OF SODIUM CHLORIDE CONCENTRATION ON NITROGEN, SODIUM AND POTASSIUM BALANCES**

| ITEMS | TAP WATER | 1.0% NaCl | 1.5% NaCl | 2.0% NaCl | +S.E. |
|---|---|---|---|---|---|
| Nitrogen, mg/kg $^{0.75}$ | | | | | |
| intake | 1099 | 1196 | 1109 | 1052 | 16.20 |
| faecal | 507 | 540 | 524 | 499 | 6.23 |
| urinary | 428 | 498 | 439 | 415 | 20.33 |
| balance | 164 | 158 | 146 | 138 | 4.47 |
| Sodium, g/day | | | | | |
| intake | 21.6 | 101.2 | 136.6 | 139.3 | 14.50 |
| faecal | 3.76 | 3.81 | 3.93 | 4.40 | 0.13 |
| urinary | 25.6 | 94.4 | 128.0 | 128.9 | 14.16 |
| balance | 2.30 | 2.99 | 4.71 | 5.99 | 0.67 |
| Potassium, g/day | | | | | |
| intake | 16.6 | 19.3 | 17.6 | 16.8 | 0.30 |
| faecal | 1.74 | 2.47 | 2.63 | 2.55 | 0.11 |
| urinary | 13.1 | 14.9 | 13.2 | 12.1 | 0.33 |
| balance | 1.67 | 1.96 | 1.81 | 2.13 | 0.14 |
| Serum levels, mg/100 ml | | | | | |
| sodium | 320 | 335 | 363 | 422 | 12.44 |
| potassium | 15.2 | 15.5 | 15.4 | 14.9 | 0.08 |

Source: KANDIL et al. (1985).

It was noted that 1.0 percent sodium chloride in the drinking water promoted a slightly better live weight gain, significantly increased dry matter intake and did not affect digestibilities. The TDN intake slightly and DCP intake significantly increased in camels receiving the 1.0 percent salt solution. Nitrogen balance decreased progressively as the salt concentration in the drinking water increased, but the effect of the 1.0 percent solution was not significant. Moreover, free water intake increased as the salt concentration increased up to 1.5 percent, but it decreased at the 2.0 percent level. Sodium and potassium retentions were also improved in camels drinking the salt waters, 30 and 17 percent at the 1.0 percent salt level. Sodium concentration in serum increased in proportion to intake, whereas potasium increased only in the 1.0 percent salt group and decreased afterwards.

The results suggested that 1.0 percent sodium chloride in the drinking water (Total sodium intake 101.2 g. Na/day, equivalent to 257 g. NaCl/day) was beneficial to camels fed high roughage rations, in support of Wilson's (1984) statement quoted above. Total sodium chloride intake of the control camels amounted to 55 g. NaCal/day, within the 30-60 g. NaCl range of frequently suggested allowances, but it was not adequate. The results further indicated that the tolerance level to sodium chloride in the camel probably lies between 1.0 and 1.5 percent, possibly similar to that of sheep at 1.3 percent, 13000 ppm. On the other hand, the 2.0 percent solution appeared detrimental as it adversley affected all the parameters studied.

Thus, increasing water salinity increased the need for drinking water, and water excretion as well, and possibly increasing urinary nitrogen excretion where SCHMIDT-NIELSEN et al. (1958) found that urinary nitrogen output in sheep was positively related to the urine flow rate. Therefore, a comprehensive investigation into the effects of water salinity and the decreasing protein intake on different nutritional and physiological aspects of camels and sheep is being undertaken. Preliminary results of the effects of water salinity, 13500 ppm. on nitrogen balance and kidney function parameters in animals receiving adequate protein intake are summarized in Table 15 (Farid, Shawket and Abou-El-Nasr, unpublished).

**Table 15**

**EFFECTS OF DRINKING SALINE WATER ON NITROGEN BALANCE AND KIDNEY FUNCTION IN CAMELS AND SHEEP**

| ATTRIBUTES | CAMELS | | SHEEP | | |
|---|---|---|---|---|---|
| | FRESH | SALINE | FRESH | SALINE | S.E. |
| Water intake, ml/kg $^{0.82}$ | 58.90 | 77.60 | 82.20 | 107.80 | 3.09 |
| Faecal water, ml/kg $^{0.82}$ | 13.90 | 21.30 | 8.40 | 11.10 | 0.64 |
| Urinary water, ml/kg $^{0.82}$ | 10.50 | 21.90 | 23.50 | 52.00 | 3.87 |
| Urinary solids, DM% | 9.81 | 7.27 | 6.32 | 5.12 | 0.40 |
| Urine flow, ml/hr./kg $^{0.75}$ | 0.63 | 1.26 | 1.03 | 2.20 | 0.09 |
| Clearance, ml plasma/hr/kg $^{0.75}$ | | | | | |
| creatinine (GFR) | 61.20 | 135.00 | 93.60 | 149.40 | 10.66 |
| urea | 25.80 | 24.90 | 19.90 | 40.40 | 5.74 |
| Clearance ratio | 0.41 | 0.20 | 0.21 | 0.27 | 0.042 |
| Urea transactions, ml/kg $^{0.75}$ | | | | | |
| filtered | 17.64 | 31.26 | 34.68 | 47.10 | 3.17 |
| reabsorbed | 10.16 | 25.38 | 27.42 | 34.38 | 2.47 |
| excreted | 7.49 | 5.88 | 7.27 | 12.72 | 1.81 |
| DN intake, mg/kg $^{0.75}$ | 338 | 347 | 461 | 499 | 13.8 |
| N-balance, mg/kg $^{0.75}$ | | | | | |
| simple | +30 | −5 | −28 | −40 | 3.81 |
| DN covariate | +48 | +31 | −46 | −76 | 5.10 |

Source: FARID, SHAWKET and ABOU-EL-NASR (unpublished).

Water salinity increased free water intake about one-third in both species, but camels consumed on the average 40 percent less water than sheep. Faecal and urinary water excretion increased in both species when given the saline water, camels consistently excreting more faecal water and less urinary water than sheep. Urine flow rate per unit metabolic size doubled in both species and the glomerular filtration rate (GPR) markedly increased. Urea clearance, on the other hand, was not affected by water salinity in camels, but it increased 2-fold in sheep.

Filtered urea increased in both camels and sheep possibly because of increased blood flow through the kidneys and the increased GFR. Camels filtered only 51 and 66 percent as much urea as sheep drinking fresh and saline water, respectively. Tubular reabsorption increased in camels more than in sheep and, therefore, urea excretion was not much affected in camels but markedly increased in the sheep.

Nitrogen balance was adversely affected in both species when the saline drinking water was used, but camels were consistently in a better state than sheep. Therefore, nitrogen balance corrected by covariance analysis for differences in digested nitrogen intake became more positive in camels and more negative in sheep. However, it appears that the effect of water salinity on nitrogen retention in camels was mainly through decreasing protein digestion and not on the kidneys where urea clearance was not affected, the increased urea filtration did not exceed tubular reabsorption capacity and urea excretion slightly decreased. This is opposit to the effect observed in sheep where water salinity affected the kidneys and not the digestive capacity. We are awaiting the coming results of the effects of water salinity where the animals are receiving suboptimal protein intake, down to 40 percent of their maintenance requirements, a situation normally stimulating the kidneys to conserve nitrogen.

## Bibliography

ABDALLA, M.A., and ABDALLA, O. (1979): Morphometric Observations on the kidney of the camel, Camelus dromedarius. *J. Anat.* 129, 45-50.

ABOU-EL-NASR, H.M. (1985): A study of the possibility of using desert agricultural by-products in feeding livestock. Ph. D. Thesis, Cairo University, Giza, Cairo, Egypt.

ACLAND, P.B.E. (1932): Notes on the camel. *Sudan Notes Rec.,* 5, 119-149.

BLIGH, J. (1959): The receptors concerned in the thermal stimulus of panting in sheep. *J. Physiol.,* 146, 142-151. (c.f. SCHMIDT-NIELSEN, 1964).

BRODY, S. (1945): Bioenergetics and Growth. Reinhold Publ. corporation.

BROOK, A.H., and Short, B.F. (1960): Sweating in sheep. *Aust. J. Agric. Res.,* 11, 557-569.

CHARNOT, Y. (1960): Repercussion de la dehydration sur la biochimie et l'endocrinologie du dromadaire. *Travaux de l'Instit. Sci. Cherifien, Ser. Zool.* No. 20, Rabbat, (c.f. SCHMIDT-NIELSEN, 1964).

EL-ZEINY, WISAM, T. M. (1986): Functional and structural evaluation of the cutaneous evaporative setup in desert camels. Ph. D. Thesis, Faculty of Science, Al-Azhar Unversity, Cairo, Egypt.

FARID, M.F.A. (1987): Unexpected aspects of nutritional physiology and the rational development of animal production in arid rangelands. *Second International Conference: Desert Development.* January, 25-31, 1987. The American University at Cairo, Egypt.

FARID, M.F.A., SHAWKET, S. M., and Abdel-Rahman, M.H.A. (1979): The nutrition of camels and sheep under stress. Proceedings, Workshop on camels. Khartoum, December, 1979. International Foundation for Science (IFS), Sweden, *Provisional Report* No. 6, 125-170.

FARID, M.F.A., SOOUD, A.O., and HASSAN, N.I. (1985a): Effects of type of diet and level of protein intake on feed utilization in camels and sheep. *Proceedings, Third AAAP Animal Science Congress.* May 1985, Seoul, Korea, 781-783.

FARID, M.F.A., SOOUD, A.O., and SHAWKET, S. M. (1985b): Water intake and excretion of camels and sheep in relation to diet characteristics and water deprivation. *Proceedings, Third AAAP Animal Science Congress.* May 1985, Seoul, Korea, 799-801.

FERGUSON, K.A., and DOWLING, D.F. (1955): The function of cattle sweat glands. *Aust. J. Agric. Res.,* 6, 640-644.

GAUTHIER-PILTERS, H., and DAGG, A.I. (1981): The Camel its evolution, ecology, behavior and relationship to man. The University of Chicago Press, Chicago.

GOTTSCHALK, L., and MYLLE, M. (1959): Micropuncture study of the mammalian urinary concentration mechanism: evidence for the countercurrent hypothesis. *Amer. J. Physiol.,* 196, 927-936.

KANDIL, H.M. (1984): Studies on camel nutrition. Ph. D. Thesis. Ain-Shams University, Cairo, Egypt.

KANDIL, H.M., SOOUD, A.O., FARID, M.F.A., EL-SHAER, H.M. and EL-ASHRY (1985): Effect of drinking saline water on feed utilization and nitrogen and mineral balances in camels. First International Conference on Animal Production in Arid zones (ICAPAZ). September 1985. ACSAD, Damascus, Syria.

KLEIBER, M. (1961): The fire of life: an introduction to animal energetics. John Wiley & Sons, Inc., New York.

LEE, D.G., and SCHMIDT-NIELSEN, K. (1962): The skin, sweat glands and hair follicles of the camel (Camelus dromedarius). *Anat. Rec.,* 143, 71-77.

LEESE, A.S. (1927): A treatise on the one-humped camel in health and disease. Haynes & Son, Stampford.

LEONARD, A.G. (1894): The camel; its uses and management. Longmans Green, London. (c.f. SCHMIDT-NIELSEN, 1964).

MACFARLANE, W.V. (1968a): Adaptation of ruminants to tropics and deserts. In: *Adaptation of domestic animals.* E.S.E. HAFEZ, editor. Lea and Febiger, Philadephia.

MACFARLANE, W.V. (1968b): Comparative functions of ruminants in hot environments. In: *Adaptation of domestic animals.* E.S.E. Hafez, editor. Lea and Febiger, Philadephia.

MACFARLANE, W.V., MORRIS, R.J.H., and HOWARD, B. (1956): Water economy of tropical Merino sheep. *Nature,* London, 178, 304-305.

MACFARLANE, W.V., MORRIS, R.J.H., HOWARD, B., McDonald, I., and Bdtz-Olsen, O.E. (1961): Water and electrolyte changes in tropical Merino sheep exposed to dehydration during summer. *Aus. J. Agric. Res.,* 12, 889-912.

MACFARLANE, W.V., MORRIS, R.J.H., and HOWARD, B. (1963): Turnover and distribution of water in desert camels, sheep, cattle and kangaroo. *Nature,* London, 197, 270-271.

MACFARLANE, W.V., and HOWARD, B. (1966): Water content and turn-over of identical twin Bos indicus and B. taurus in Kenya. *J. Agric. Sci., Camb.,* 66, 297-302.

MACFARLANE, W. V.; HOWARD, R. J. H., and SEIBERT, B. D. (1967): Water metabolism of Merino and Border-Leicester sheep grazing saltbush. *Aust. J. Agric. Res.,* 18, 947-958.

MACFARLANE, W.V., and HOWARD, B. (1974): Ruminant water metabolism in arid areas. In: *Studies of the Australian arid zone. I. Animal production.* A.D. WILSON, editor, CSIRO, Australia, 7-22.

MALOIY, G.M.O. (1972): Renal salt and water excretion in the camel (Camelus dromedarius). *Symp. Zool. Soc. London,* 31, 243-259. (c.f. WILSON, 1984).

NEWMAN, D.M.R. (1979): The feeding habits of the old and new world camels as related to their future role as productive ruminants. Workshop on camels. Khartoum, december 1979. International Foundation for Science (IFS), Sweden, Provisional Report No, 6, 171-200.

PECK, E.F. (1939): Salt intake in relation to cutaneous necrosis and arthritis of one-humped camels (Camelus dromedarius) in British Somaliland. *Vet. Rec.,* 51, 1355-1360. (c.f. SCHMIDT-NIELSEN, 1964).

PUROHIT, G.R. (1979): A note on seasonal variation in distribution of body water in various compartments of indigenous and cross bred sheep. *Trans. Insdt. & Ucds.,* India, 4, 118-120.

SCHMIDT-NIELSEN, K. (1964): Desert animals: Physiological problems of heat and water. Oxford University press.

SCHMIDT-NIELSEN, B., SCHIMDT-NIELSEN, K., HOUPT, T.R., and JARNUS, S.A. (1956): Water balance of the camel. *Amer. J. Physiol.,* 185, 185-194.

SCHMIDT-NIELSEN, K., SCHMIDT-NIELSEN, B., JARNUM, S.S., and HOUPT, T.R. (1957): Body temperature of the camel and its relation to water economy. *Amer. J. Physiol.,* 188, 103-112.

SCHMIDT-NIELSEN, B., OSAKI, H., MURGOUGH, H. J., Jr., and O'DELL, R. (1958): Renal regulation of urea excretion in sheep. *Amer. J. Physiol.,* 194, 221-228.

SCHMIDT-NIELSEN, K., CRAWFORD, E. C., NEWSOME, A.E., RAWSON, K.S., and HAMMEL, H.T. (1967): Metabolic rate of camels: effect of body temperature and dehydration. *Amer. J. Physiol.,* 212, 341-346.

SERGENT, E., and LHERITIER, A. (1919): Note sur la temperature rectale des dromedaires. *Compt. Rend. Soc. Biol.,* 82, 172-175. (c.f. SCHMIDT-NIELSEN, 1964).

SHAWKET, S. M. (1976): Studies on the rumen microorganisms. M. Sc. Thesis, University of Alexandria, Egypt.

SIEBERT, B.D., and MACFARLANE, W.V. (1971): Water turnover and renal function of dromedaries in the desert. *Physiol. Zool.,* 44, 225-240.

SPERBER, I. (1944): Sutdies on the mammalian kidney. *Zool. Bidrag fran Uppsala,* 22, 249-431. (c.f. MACFARLANE, 1968b).

SOOUD, A.O. (1980): Comparative studies on digestion and food utilization in camels and sheep. Ph. D. Thesis, University of Ain-Shams, Cairo, Egypt.

WILSON, R.T. (1984): *The Camel.* Longman, London, p. 223.