The ship of the desert. The dromedary camel *(Camelus dromedarius)*, a domesticated animal species well adapted to extreme conditions of aridness and heat

S. Bornstein[1*]

[1] The National Veterinary Institute, Box 7073, S-750 07 Uppsala, Sweden

* Veterinary consultant for a SAREC (Swedish Agency for Research Cooperation with Developing Countries) sponsored Camel Project in Somalia.

Abstract: The dromedary camel *(Camel dromedarius)* is extremely well adapted to life in hot and arid lands. In terms of physiological adaptation to heat and water deprivation it surpasses by far every other large animal of which data have been collected. None of the adaptive mechanisms to cope with the environmental stresses are unique to the Arabian camel, but the efficiency of its adaptation is superior.

At high ambient temperatures the camels adapt to the scarcity of water by reducing their faecal, urinary and evaporative water losses.

During dehydration, the kidneys reduce water losses both by decreasing the glomerual filtration rate and by increasing the tubular reabsorption of water. Also their ability of regulating their body temperature from 34.5-40.7°C conserves a lot of water, when most needed.

Key words: heat-adaptation, water conservation

Rangifer, Special Issue No. 3, 1990: 231-236

Introduction

For hundreds of years the camel *(Camelus spp)* had been exploited by man in Asia and Africa in arid and semiarid areas - often being the only supplier of food and transport for people.

In the aftermath of the devastating droughts, which hit Africa during the 1970s and 1980s an interest has awakened in this beast of burden and provider of milk, meat, wool, fibres and hides. The camels are truly multi-purpose animals. They have shown to be better adapted to extreme conditions in most aspects than other domestic ruminants husbanded in the harsh environments of arid and semiarid Africa and Asia.

Camelus spp

There are two species of camels belonging to the camelidae. The two- humped or Bactrian camel *(Camelus bactrianus)* is found in Asia and thrives particularly in cold and arid regions.

The one-humped or dromedary camel *(Camelus dromedarius)* also called the Arabian camel, because it is closely linked with Arab history and culture. The dromedary is found in al-most all the hot, arid and semiarid regions of the "old world": throughout northern Africa and parts of Asia.

Origins of the Camelidae

The camels belong to the *Camelidae* in the ruminant suborder *Tylopoda* of the order *Artiodactyla* (even-toed Ungulates). The Tylopoda (padfooted) walk on cushioned pads at the end of the digits (the second and fourth).

The *Camelidae* differ from other true ruminants in not having horns or antlers. Their forestomachs are different morphologically and physiologically. A special feature of the *Camelidae* is the oval shape of their red blood-cells - unique among mammals.

Fossils show that the early evolution of the *Camelidae* took place in North America. The earliest found ancestor (Protylopus) from the Upper Eocene period was no bigger than a hare.

The *Camelus* spp appeared during the Pleistocene period, and during one of the ice ages when there was a land-bridge between Alaska and Siberia (the present Bering strait) "early camels" spread into Asia.

During the migration and evolution of the camels in the "Old World", the camel groups died out in Northern America. However, some Camelids had migrated to South America and evolved to the present South American Camelids; the three species of the genera *llama* and the one species of the genus *Vicugna*.

Distribution

The population of the dromedary camel is much more numerous then the Bactrian camel and constitutes about 90 per cent of the genus Camelus in the world.

More than 80 per cent (12 million) of the Arabian camels are found in Africa in more than 18 countries, forming an important part of the domestic livestock population.

In Asia the dromedary camels are found in the Middle East including the South Arabian peninsula, Turkey, Iran, Afghanistan, North Western India, China (Western Sinkiang) and in the south-western Soviet Union (mainly Turkmenistan).

At the northern and eastern edges of the dromedary camel's range in Asia one finds the Bactrian camel in the mountainous regions of southern Russia and in the cold deserts of China including Mongolia. The total population of Bactrians in China is estimated to be about 600 000 (some sources say over 1 million, Mason, 1984). 60% of these animals are found in inner Mongolia. The limits of the camel-breeding area follow the *isohyet* for 50 cm of rain and the Bactrian camels are not found where the mean annual temperaure is above 21° C (Mason, 1984).

The camel today is essentially a domestic animal of pastoralists and agropastoralists. However camels are also found in areas of permanent cultivation i. e. desert oases, along the Nile in Egypt or in Indian and Pakistani villages.

The dromedary camels have very special anatomical and physiological characteristics, which enables the animals to live, reproduce and produce milk and meat and to work under extreme conditions of heat and aridness - even during periods of drought when cattle, sheep and goats barely survive.

Anatomical advantages

Skin and coat

Insulation from high environmental temperature depends on the quality (i.e. density, thickness, texture, colour) of the coat of the animal, the colour and quality of the skin and the presence of layers of fat in the subcutis.

In theory animals exposed to high levels of solar radiation should preferably have a smooth reflective coat, which should not be too thick to prevent evaporation at the skin surface nor too thin, in order to avoid too much heat striking the skin surface.

Most types (breeds) of dromedary camels living in hot arid environments conform to the above requirements. The "summer" coat of dromedary camels are usually light in colour, rather thin and sleek, effectively reflecting the solar rays.

Size

The large size and height of the camel can be of some advantage in heat regulation. (The Arabian camel stands over 2 meters at the shoulders and an adult camel weighs about 400-700 kg). A large body mass heats up much more slowly than a smaller mass exposed to the sun (Yagil, 1985).The long legs and the large humps, containing adipose tissue, gives to the camel a large skin surface in relation to the body mass, which is another advantageous feature in regards to heat regulation.

The height above the ground (long legged) allows the desert winds free access to the body thus in some circumstances cooling it effectively. It also enables the camels to browse high above the ground reaching 3.5 meters into the canopies of trees and bushes. This characteristic together with their preference to browse on many kinds of bushes makes them an excellent complement for multi-species herds in different kinds of rangelands, increasing the productivity of the land without really competing with other livestock (Evans and Powys,1984). The camels graze and browse in ways similar to some wild ungulates. They keep moving while feeding, nibbling a few bites here and there from one plant to another. Their long muscular legs allow them to cover vast distances in search of water and food. Even on rich pastures they may cover five kilometres in two and a half hours while grazing and browsing (Gauthier-Pilters and Dagg, 1981)

Water conservation

The camels' ability to survive long periods without water is legendary. This ability varies between breeds, and is influenced by climatic factors, the quality and quantity of the forage, and its water content, the age of the animal and the type of work it is subjected to (Gauthier-Pilters and Dagg, 1981; Schmidt-Nielsen, 1964). It is also influenced by training (management).

During the rainy season the herbage is often rich in water and the camels will also find surface water in natural dams. During the winter and cool season (6-7 months) in the Sahara the camels can go without water. They do not even drink when offered water. The fodder has enough moisture for the maintenance and productive requirements (Gauthier-Pilters and Dagg, 1981)

During the dry season when pastures have dried up camels are taken to water every 6-10 days. In extreme situation they can go without water for over a month (cattle have to be watered every 2-3 days).

When the mean temperature reach 30-35°C in the Sahara and in the Sahel, camels can go 10-15 days without water but when the temperature exceeds 40°C, shorter periods between watering is necessary (Gauthier-Pilters and Dagg, 1981).

According to Schmidt-Nielsen et al. (1956) a camel can lose water (dehydrate) of more than 25% of its body-weight. Gauthier-Pilters and Dagg (1981), when studying camels in the Sahara during the summer, saw camels of 500 kilos body-weight drinking 150-200 litres of water after being without it for 5-7 days. The camels compensated their dehydrated state by drinking over 30% of their weight. This they usually do very quickly. In a couple of minutes they have drunk most of what they need. A well nourished camel will drink 10-20 litres per minute.

The more dehydrated a camel becomes the more it conserves water (Schmidt-Nielsen et al., 1956; Charnot, 1958; Clair, 1962). Camels do not store water as was thought not so long ago. They conserve it by help of many different physiological mechanisms.

Temperature regulations

Body-temperature

Instead of dissipating most of its heat through loss of water during the hot part of the day by sweating, the camel, when dehydrated can store some of the heat allowing its body temperature to rise as high as 40.7°C. During the evening and cooler part of the night the temperature of the body can fall to a little above 34°(Schmidt-Nielsen, 1964). This difference in temperature (34.5-40.7°C) of 6.2° of a camel weighing 500 kg is equivalent to approximately 2 500 kcal, which by dissipation via evaporation would require nearly five litres of water (sweat), which is thus saved,

Evaporation

Camels have sweatglands in their rather thick skin (Sekles et al., 1979). There are an average of 200 per cm^2 on the body, the same amount as found in man. (Cattle have 4-8 times as many.) Sweating is said to be one of the major mechanism for increasin evaporation in camels (Schmidt-Nielsen et al., 1981). However, the camels do not start sweating when dehydrated until their upper limit of heat storage is reached.

At high ambient temperatures the respiratory rate increases slightly in the camel from 6-11 to 8-18 breaths per minute (in the Sahara, Schmidt-Nielsen, 1964) and in Australia from 10-12 to 20-24 (Macfarlane, 1968). This raise in respiration rate does not significantly increase evaporation or loss of water (compare the panting in the dog).

The sweat evaporates directly from the skin surface in the dromedary camel rather than from the tip of the hairs as it does on heavily furred animals. Latent heat of vaporization is therefore drawn directly from the skin. Evaporation that takes place directly on the skin saves more energy and cools the skin more effectively than if the evaporations took place at the tip of the hairs.

It has been estimated that during the cooler months (Sahara) 50% of the total water loss of camels are from evaporation (Schmidt-Nielsen, 1956). During midsummer 85% of the total water losses were from evaporation declining to 65% in the dehydrated animal.

Water conservation via kidneys and gut

Another water conserving adaptation mechanism of the camel is the capacity to produce very little urine and dry faeces.

The alimentary tract in the camel is regarded to be the main provider of fluids for the body and the kidneys are vital in retaining as much water as possible by helping in maintaining the extracellular fluid composition and volume brought about by glomerular filtration, tubular reabsorption and tubular secretion. Macfarlane (1977) calculated that the daily urine volume excreted by dehydrated camels was one thousandth of the animals body weight. Dehydrated sheep living in the same environment excreted one two-hundredth of its body weight. If an adult man (80 kg) would excrete urine as the dehydrated camel does, it would mean a daily volume of 0.08 litres.

In the literature a wide variation of data on the volume of urine excreted by camels are found. In Algeria urine volumes declined from 0.75 litres a day when water was given ad libitum to 0.5 litres when the camels where dehydrated (Schmidt-Nielsen et al., 1956). In Kenyan camels urine volumes declined from 0.8 to 0.2 litres per day (Maloiy, 1972). Siebert and Macfarlane (1971) reported declining volumes from 2.9-8.6 litres to 0.7-1.7 liters per day in camels in Australia and in Morocco Charnot (1958) found urine volumes declining from 5 liters to 1.5 litres per day in the camels studied. This great reported variation in urine volumes are not only due to the different methods (accuracy) in collecting the urine by the researchers but also due to the type (breed) and size of animal studied , what climatic stress (temperature, solar radiation etc) the animal investigated was exposed to and the quality and water content of the fodder given and for how long the animal had been deprived of water (dehydrated).

During dehydration the kidneys reduces urinary water loss both by decreasing the glomerular filtration rate and by increasing the tubular reabsorption of water (Maloiy, 1972). Sperber (1944) found that animals who efficiently conserve water via their kidneys have a proportionally thicker medulla (higher ratio of the medulla/cortex) than animals who are less efficient in concentrating their urine. Abdalla and Abdalla (1979) could verify that the kidneys of the dromedary camel possessed anatomical structural requirements to produce hypertonic urine. The medulla to cortex ratio was 4:1.

The small quantites of urine produced are also well utilized by the animals for cooling by urination onto the backlegs and tail.

Craving for salt

The ability to concentrate its urine enables the camel to tolerate even to require water and plants with high salt content, thus salt (NaCl) is a very important part of the camels diet. Traditional grazing management by most camel beeeders involve regular supplementation of salt, usually by taking the camels to saline pastures, saline wells or salty earth, at least twice a year. It is believed that they will loose condition, abort, give less milk and will be prone to diseases like skin necrosis and arthritis (Peak, 1939), if not given enough salt.

Conservation of urea

The kidneys of the camel excrete small amounts of urine when it is necessary to conserve water. the animal can also produce urine with extremely low concentration of urea, when fed a diet low in proteins (Read, 1925; Schmidt-Nielsen et al., 1957). The urea in the camel formed during protein metabolism is thus not necessarily excreted. It may pass back into the rumen from the blood plasma via the saliva and through the rumen wall. Thus the camel can conserve and recycle urea for protein synthesis when food is low in protein or when growing or pregnant. This mechanism of recycling urea is also found in true ruminants. Valtonen (1979) found in reindeer (confirming Schmidt-Nielsen findings in camels) that the recycling mechanism of urea is coupled to a decrease in water intake.

Metabolic rate

Another adaptive mechanism of this extraordinary animal includes its metabolic activity, which is sensitive to temperature fluctuation. Like all other mammals, exposed to high ambient temperatures, the metabolic rate increases with increasing body temperature. However, in camels dehydration leads to a reduction in the metabolic rate. There is inhibition of thyroxin production during periods of dehydration which decreases pulmonary water loss and reduced metabolism (Yagil et al., 1978).

The metabolic rate of dromedary camels has been shown in the desert and sub-desert of Australia to be about half of that of cattle living in the same environment (Macfarlane et al., 1971). The turnover of water is also low in camels grazing during summer in the desert - about half of the turnover rate of cattle studied in the same area of Australia. The water turnover rate for the camels in the hot season is twice as high as in winter and it is higher in lactating than in non-lactating camels.

References

Abdalla, M.A and Abdalla, O. 1979. Morphometric observations on the kidney of the camel, Camelus dromedarius. - *Journal of Anatomy* 129:45-50.

Charnot, Y. 1980 *Repercussion de la déshydration sur la biochimie et l'endocriniologie du dromadaire.* Thesis, Faculté des Sciences Université de Paris.

Clair, M. 1962.*De la résistance du chameau a la Soif.* Paris: R. Foulon.

Evans, J.O. and **Powys, J.G.** 1984. Camel husbandry in Kenya: Increasing the productivity of Ranch lands. - *In: The Camelid - an all- purpose animal*,Vol.1. Proceedings of the Khartoum Workshop on Camels, 1979. Scandinavian Institute of African Studies, Uppsala.

Gauthier-Pilters, H. and **Dagg, A.** 1981. *The Camel.* University of Chicago Press.

Macfarlane, W.V. 1964. Terrestrial animals in dry heat; Ungulates. Dill, - *Handbook of physiology*.Section 4. Adaptation to environment, pp. 509-539. (American Physiological Society, Washington).

Macfarlane, W.V. 1968. Comparative functions of ruminants in hot environments. - *Hafez, Adaptation of domestic animals*, pp. 264-276 (Lea & Febiger, Philadelphia).

Macfarlane, W.V., Howard, B., Haines, H., Kennedy, P.J. and **Sharpe, C.M.** 1971. Hierachy of water and energy turnover of desert mammals. - *Nature* 234:483-484.

Macfarlane, W.V. 1977. Survival in arid lands. - *Australian Natural History* 29,18-23.

Maloiy, G.M.O. 1972. Renal Salt and Water Excretion in the camel *(Camelus dromedarius)*. - In: *Symposia of the Zoological Society of London*, No. 31, 234-259.

Mason, J.L.1984. Origins, Evolution and distribution of Domestic Camels. - In: *The Camelid - an all- purpose animal*, Vol. 1. Proceedings of the Khartoum Workshops on Camels, 1979. Scandinavian Institute of African Studies Uppsala.

Peck, E.F. 1939. Salt intake in relation to cutaneous necrosis and arthritis of one-humped camels *(Camelus dromedarius*, L.) in British Somaliland. - *The veterinary Record* 51, 46, 1355-1360.

Read, B.E. 1925. Chemical constituents of camel's urine. - *Journal of Biological Chemistry* 64, 615-617.

Schmidt-Nielsen, K. 1956. Animals and arid conditions: Physiological aspects of productivity and management. - In: *The future of arid lands*, pp. 368-82. Washington, D.C.: American Association for the Advancement of Science.

Schmidt-Nielsen, B., Schmidt-Nielsen, K., Houpt, T.R and **Jarnum, S.A.** 1956. Water balance of the camel. - *American Journal of Physiology* 185:185-94

Schmidt-Nielsen, B., Schmidt-Nielsen, K., Houpt, T.R. and **Jarnum, S.A.** 1957. Urea excretion in the camel. *American - Journal of Physiology* 188:477-484.

Schmidt-Nielsen, K. 1964. *Desert animals: Physiological problems of heat and water.* - Clarendon Press: Oxford.

Schmidt-Nielsen, K., Crawford, E.C. and **Hammel, H.T.** 1981. Respiratory water loss in camels. - In: *Proceedings of the Royal Society, London* 211:291-303.

Sekles, E., Cohen, R., Etzion, Z. and **Yagil, R.** 1979. Sweat glands in the Bedouin camel. - *Refuah Veterinarith* 36, 71.

Siebert, B.B. and **Macfarlane,W.V.** 1971. Water turnover and renal function of Dromedaries in the Desert. - *Physiological Zoology* 44:225-240.

Sperber, J. 1944. Studies on the mammalian kidney. - *Zoologiska bidrag från Uppsala*, Uppsala, 22, 249-431.

Valtonen, M. 1979. Renal responses of Reindeer to high and low diet and Sodium supplement. - *Journal of the Scientific Agricultural Society of Finland* 51 (6), 381-419.

Yagil, R., Etzion, Z. and **Ganani, J.** 1978. Camel thyroid metabolism: effect of season and dehydration. - *Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology* 45, 540-544.

Yagil, R. 1985. *The desert Camel.* - Karger.