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Faculty of Tropical AgriSciences

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The Adaptation of Camels to Extreme Environments

Bachelor Thesis

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Declaration

I hereby declare that this B.Sc. thesis entitled "Adaptation of Camels to Life in Extreme Environments" is my own work and all the sources have been quoted and acknowledged by means of complete references. I agree with the work to be stored and available for educational purposes in the library of CULS.

In Prague: 23 April 2014

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Radim Sedláček


Photo by author

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Abstrakt

Adaptace velbloudů do extrémních podmínek

Termoregulační mechanismy některých savců umožňují velice efektivní hospodaření s teplem získaným z okolního prostředí ale i z dopadajících slunečních paprsků. Cílem práce bylo zjistit, zda i velbloudi záměrně nastavují tělesnou osu vůči slunci tak aby mohli regulovat množství přijímaného okolního tepla. Během pozorování byly v intervalech 10 minut zaznamenávány změny v orientaci tělesné osy velbloudů vzhledem ke slunečnímu záření, ale taktéž změny v chování zvířat. Rovněž byl pomocí kompasu zjišťován vliv magnetismu na orientaci zvířat směrem k světovým stranám, a to ve stejných intervalech. Orientace zvířat byla podle kompasu rozdělena do 8 kategorií, zatímco vlivy atmosférické teploty na orientaci velbloudů byly hodnoceny ve třech teplotních rozmezích a změny v chování řazeny do 10 skupin. Literární rešerše odhalila u velbloudů nespočet unikátních adaptačních zvláštností, zatímco osmnáctidenní terénní výzkum přinesl velice zajímavé poznatky. 144 hodin terénního průzkumu ve dvou zoologických zahradách poskytlo přes 4750 záznamů v každé kategorii. Statistické vyhodnocení dat prokázalo, že frekvence paralelní orientace velbloudů vzhledem k dopadajícím slunečním paprskům byla četnější za vysokých teplot, zatímco četnost orientace kolmo ke slunečním paprskům se zvyšovala s klesajícími teplotami prostředí. Tyto výsledky potvrzují teorii o podvědomém směřování tělesné osy velbloudů v kontextu termoregulačního chování skrze sluneční energii. Na druhou stranu nám výsledky nepotvrdily žádné významné preference velbloudů vzhledem ke světovým stranám, což neprokazuje vliv magnetického pole Země na orientaci velbloudů, tak jako tomu je u skotu, srnce obecného, myší i dalších savců.

Klíčová slova: sluneční záření, orientace tělesné osy, magnetismus, termoregulační chování, kopytníci, *Camelus*

Author’s abstract

The Adaptation of Camels to Extreme Environments

Thermoregulatory behaviour in context of solar radiation allows some mammals effectively regulate the amount of radiant heat obtained from an environment. Therefore the aim of the thesis was to found out whether camels adapted this unique mechanism, too. Body axis orientation of each camel relative to incident solar radiation was recorded every 10 minutes as well as the direction body alignment relative to magnetoreception and behavioural changes. Compass orientation was classified into eight 45° arcs relative to magnetic north whilst dry-bulb temperatures were divided into three categories and behavioural changes classified into ten specific categories. Whereas a bibliographic research revealed a range of unbelievable adaptations of the camel to survive in ruthless conditions of its natural habitat, the field research pointed out some important findings. Together 18 days precisely 144 hours of data were collected during field research. In total 9 camels from two Czech zoological gardens provided us with 4750 scan samples. Present study revealed that frequency of orientation parallel to incident solar radiation increased as ambient temperature went higher while perpendicular orientation of camels was more frequent in cold temperatures. Those results of field research prove a theory that camels adapted their behaviour in context of solar radiation and ambient temperatures. On contrary, the camels did not preferentially align northerly or in any other cardinal direction which perhaps reveals that camels have not adapted to magnetoreception in comparison with roe deer, cattle, mice and other mammals.

Key words: solar radiation, body axis orientation, magnetic orientation, thermoregulatory behaviour, *Camelus*, ungulates

Contents

List of tables and figures

List of the contractions

BV	blood volume
CULS	Czech University of Life Sciences
FAO	Food and Agriculture Organization
ICF	intercellular fluid volume
ISF	interstitial fluid volume
ITIS	Integrated Taxonomic Information System
IUCN	International Union for Conservation of Nature
OBLB	orientation oblique back to the sun
OBLF	orientation oblique facing to the sun
PARB	orientation parallel back to the sun
PARF	orientation parallel facing to the sun
PERP	orientation perpendicular to the sun
PV	plasma volume
RCV	red cell volume

1 Introduction

A camel became an icon of human survival in the hot dry zones of the northern hemisphere as well as the mountains of central Asia represented by Mongolia at altitudes of up to 2 000 m (Baimukanov, 1989). A camel symbolizes the essential component of the culture and agriculture in the arid regions. There are three species distinguished in the genus *Camelus*, namely the one-humped camel (*Camelus dromedarius*), also known as the camel of plains, then the wild Bactrian camel (*Camelus ferus*) listed as Critically Endangered by the International Union for Conservation of Nature (IUCN) (Hare, 2008) and the third species represents the two-humped or Bactrian camel (*Camelus bactrianus*) which is also called the camel of mountains (Boisserie *et al.*, 2005; Hassanin *et al.*, 2012; Kaczensky, 2014). The dromedary camel was distributed throughout the tropical and subtropical dry areas of northwest India, North Africa, Arabian Peninsula and Western Asia. The natural distribution is limited by wet climates and the occurrence of the tsetse fly. Isolated introductions also took place in parts of the United States of America, the Caribbean, Central America, southern Africa, Europe and Australia (Wilson, 1984). Interest in camels has increased especially in Asia which imported about 1.4 million of camels in last decade, particularly 245.000 dromedary camels in 2010 (FAO, 2014). The two-humped camel inhabits places specific for a monotonous desert relief, great insolation, low precipitation, and very infrequent cover of drought-resistant vegetation. In exceptional circumstances, the Bactrian camels are capable of cross passing at higher altitudes, even when it is snowing. The Bactrian camels endure well the continental desert climate with sharp frosts in winter and extreme temperatures in summer (Schmidt-Nielsen, 1964; Chapman, 1985).

Camel is used for several purposes for which its role is invaluable. It is used as a beast of burden for transporting goods and people as well as for providing milk. Milk is often the only regular food source for its owners. Camel's meat, wool and leather are also widely utilized (Faye and Esenov, 2005; Ahmad *et al.*, 2010). In view of unassuming hard workers, dromedary camels were introduced into Australia on a large scale between 1840 and 1907. These very effective helpers were used mostly as a transport animals and beasts of burden during establishment of Australian railways and during the constructions of telegraph lines in semi-arid and arid parts of Central and Western Australia. As the motor transport and the capacity of railway network increased, many camels were no longer needed and therefore released into the wild, where the camels successfully reproduced thanks to their adaptations to the harsh environment of desert. Today the feral camels have spread across arid and semi-arid areas of the Northern Territory, Western Australia and South Australia, and into parts of Queensland and they became a cause of environmental, cultural and economic problems all over its extensive range. (The Australian Government. 2009; Dörges *et al.*, 1992). There were over a million feral camels in the rangelands of Australia in 2009 and this number has been supposed to double in the next 8-10 years. No recent information was found on actual numbers of feral camels in Australia. Spencer and Woolnough (2010) only mentioned the trend of feral camels in Australia increases about 80,000 camels per year. This large population of feral camels is having significant negative impacts all over its extensive range. Moreover they are expanding into new areas (El-Keblawy, 2009; The Australian Government, 2009). The two crucial tasks are the reduction of the currently over abundant feral camel population in and build a legacy that will sustain protection of the rangeland in Australia (The Australian Government. 2009; Dörges *et al.*, 1992).

Although interest in science and environment increases worldwide, our knowledge of behavioural thermoregulatory strategies used by large mammals to avoid or utilize directly the energy in solar radiation is based on just a few empirical studies describing for example shade-seeking and the principal responses of some species to excess radiant heat load (Maloney *et al.* 2005; Hetem *et al.*, 2011) but not much was mentioned about thermoregulatory behaviour under solar radiation in the context of overall behaviour patterns (Mitchell *et al.* 2002; Maloney *et al.* 2005). Especially the number of works engaged in the topic of thermoregulatory behaviour in camels is limited. Therefore I have decided to contribute to the camel research and commenced an ethological observation of camel herd living in captivity of Czech zoological gardens in Prague and Usti nad Labem.

1.1 Aims of the thesis

The aim of the thesis was to summarize the current knowledge about anatomical and physiological adaptations of camels as well as their behaviour and ability to overcome extreme factors such as long-term high temperatures, insufficiency of drinking water and nourishment. Another task was to describe homeostatic factors affecting thermoregulatory behaviour and dependence of season on activity of animals. The field research also investigated whether camels tend to orient their body axis northerly in relation with field lines of magnetic field of the Earth or not. Further aim was to verify by field research whether camels intentionally change their body position parallel according to the direction of solar radiation during the hot summer days. In this case they would receive less sunlight which would represent the hypothesis of camel adaptation to high temperatures. Both the field research and ethological observation of camel herd living in captivity of Czech zoological gardens was made to detect veracity of the claim.

2 Bibliographic research

2.1 General information about camels

2.1.1 Classification

The camel from the genus *Camelus*, subfamily *Camelini*, family Camelidae and suborder Tylopoda, together with the suborder Suina and Cetruminantia, used to belong to the order of Artiodactyla also called even-toed ungulates (Komárek *et al.*, 2001). According to the recent genetic study (Boisserie *et al.*, 2005), the cetaceans (whales, dolphins and porpois) is expected to be the modern sister group of hippos (Hippopotamidae). Therefore a new order Cetartiodactyla was created. The suborder Tylopoda, including family Camelidae and suborder Artiofabula including family Cetacea could have been placed together for its deep relationships found in the research. Catertiodactyla is one of the most diversified orders of mammals comprising all artiodactyls (ruminants, pigs, peccaries, hippos, camels and llamas) and the cetaceans (whales, dolphins and porpois). There are currently recognized 332 extant cetartiodactyl species, which are classified into 132 genera and 22 families. The Camelidae family is represented by three genera: The genus *Lama*, the genus *Vicugna* and the genus *Camelus*. The *Camelini* subfamily is divided into three genera: *Camelus dromedarius, Camelus ferus* and *Camelus bactrianus bactrianus*. The two species *Camelus dromedarius* and *Camelus bactrianus* were first named by Linnaeus in 1758 however Przewalski devided the specie *Camelus bactrianus* into two subspecies *Camelus bactrianus bactrianus* and *Camelus ferus* (wild Bactrian camel) in 1878 (IT IS, 2014). Bactrian camels with common name two-humped camels are native to the mountains of China, Mongolia or Kazakhstan, and they are also known as Old World camels, whereas lamas that are native to the Andes in South America are named as New World camels (Lensch, 1999).

2.1.2 Domestication and origin of camels

In past, Guirgis (1997) believed that the ancestors of the current camels migrated by way of land bridges across the Bering Strait to Siberia and to South America across the Isthmus of Panama and differentiated further into several species and varieties about fifty million years ago (Komárek *et al.*, 2001). However the Camelids were considered to have developed from the wild camel (*Camelus ferus przewalski*) in North America in the Pleistocene age (Bird *et al.*, 2012; Lensch, 1999). Muctar (1990) states that the one-humped camels were domesticated around 3,000 B.C. in Southern Arabia (Muctar, 1990), at first for transport and later because of its meat, milk, wool and as a carrier animal (Lensch, 1999). Nevertheless, Meredov (1989) mentioned that the dromedary was independently domesticated in Turkmenistan and in Arabia 5000-6000 years ago. The immemorial Arvana dromedaries were used for breeding strong hybrids that were capable of great endurance. The best hybrids were obtained when crossing Arvana sires with Kalmyk Bactrian females. However, the Turkmens do not bred from hybrids (Faye and Esenov, 2005; Meredov, 1989). The feral camels found nowadays in Australia are a crossbreed of variety of camel types that were introduced into Australia mostly from India. "They included the large, fleece-bearing, two-humped Bactrian camel of China and Mongolia, the elite Bishari and Bikaneri riding camels of Arabia, and the powerful, freight-carrying lowland Indian camels, capable of moving huge loads of up to 800 kilograms" (Dörges *et al*., 1992)"

In these days an increasing demand for camel meat, milk and wool is noticeable. It might be due to growth of human population and extension of the desert in the Sub-Saharan region. Camels are also used more as work and pack animals in places where the fuel prices are high. In past Incas used the llamas, also known as remarkably proficient climbers, on their transport tracks through the cold dry terraced mountains of the Andes in South America (Lensch, 1999). Nowadays they are increasingly introduced and bred in North America for meat fibre and as pet animals (Faye and Esenov, 2005; Muctar, 1990).The two-humped Bactrian camel lives in places specific for a monotonous desert relief, intensive sunrays, low precipitation, and very infrequent cover of drought-resistant vegetation. They inhabit Mostly the Mongolian mountains at altitudes more than to 2,000 m. In exceptional circumstances, the two-humped camels are capable of cross passing at higher altitudes, even when it is snowing. (Bekele, 2010; Baimukanov, 1989). The Bactrian camels endure well the continental desert climate with sharp frosts in winter and extreme temperatures in summer. Although Lensch (1999) states that Cave paintings testify that the Bactrian camel had to be domesticated between 3,000 BC and 1,800 BC in Mongolia during the Neolithic age because word “bactrianus” comes from Bactria, the kingdom at the foot of the Hindu Kush Mountains of ancient Persia (Lensch, 1999). However Baimukov (1989) suggest that the domestication of camel took place about 5000 years B.C. The Bactrian camel population in Mongolia was 591,500 in 1980 whereas 859,100 in 1960. Therefore the government intended to increase the number to 800,000-1 000,000 animals (Chapman, 1985) which was realised and its todays population counts more than a million two-humped camels.

2.1.2.1 Widespread of camels in the world

Ramet (2001) says that the numbers of camels in worldwide history is rather difficult to register as there is not a sufficient record of this kind of date. He mentioned that the sedentarization of nomads; extreme droughts and mechanization of transport could have been the reasons for a decrease in camel numbers noticed between 1950 and 1980. Nowadays there are about 26 million camels on the Earth, of which approximately 23 million are dromedaries, 1 million feral camels and the remaining are Bactrian camels (FAO, 2014) including less than 900 critically endangered wild Bactrian camels *(Camelus ferus)* that inhabit plains of the Great Gobi Desert with presence of sufficient amount of plants, medium elevation and an appropriate distance to water (Kaczensky *et al.*, 2014). Then about 22.5 million (85%) are found in arid and semi-arid African lands, the biggest spread of camels is to be found in the Eastern Africa (43% worldwide) particularly in the horn of the African continent, including Somalia, Sudan, Ethiopia, Kenya, Eritrea and Djibouti. In Africa there are different densities where countries such as Somalia raise 7 million dromedaries which represent 26% of the world population. This is followed by dromedaries of Sudan (4.7 million), Niger (1.7 million), Mauritania (1.4 million), Chad (1.4 million) and Mali with Ethiopia where there are nearly a million dromedary camels, which is the same population as the one in Pakistan. Europe has the least numbers of 7,000 camels. When it comes to the Bactrian camels the biggest population can be seen in Mongolia (280,000) followed by China (256,000) or Kazakhstan (169,600) (FAO, 2014). Nevertheless the two humped camels inhabit also mountains, plains and deserts of Kyrgyzstan and Tajikistan. Then both dromedary and Bactrian camels can be found in Azerbaijan, Uzbekistan and Turkmenistan (Köhler-Rollefson *et al.*, 2001) Only to compare the number of camels doubled worldwide in last fifty years and there are nowadays about 5 million camels more on Earth since 2003. In following Figure1, there is no population of camels noticeable in the Southern Africa because FAO states only 87 camels living in this part of African continent (FAO, 2014).

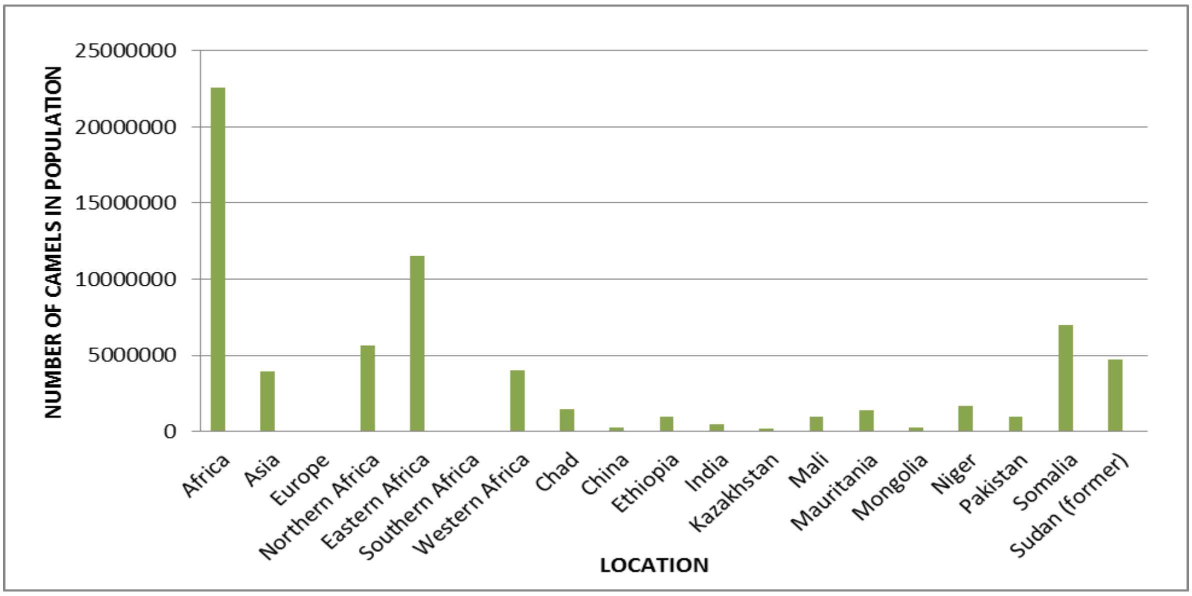

Figure 1. Widespread of camels across the world in 2011.

(Source: FAO. 2014. FAOSTAT: Production - Live animals. Available at http://faostat.fao.org/: Accessed 2014-03-26.)

Camel is the only animal that is capable of survival and production of milk and meat for the benefit of people native to these dry places, where no other animal can survive thanks to its tolerance of high ambient temperatures, drought and disease, and by utilizing a wide range of plant species not pastured by other livestock (Ahmad *et al.*, 2010; Mirkena *et al.*, 2010). In these drought-stricken regions of the world, where there is a great deal of population starving according to lack of food and malnourishment, the camel milk is superbly adapted to the needs of the young calf and the owners (Muctar, 1990). Gauthier

Pilters and Dagg (1981) state in their book that camels were used even in Egypt during Napoleon Bonaparte's campaign there. However French units had to be formed by camels with non-Egyptian origin as they did not know riding camels in Egypt. In the beginning they used 100 animals and soon there were 700 camels ridden by hussar soldiers. Later on French mobilized camels also during occupation of Algeria. 20,000 of 34,000 camels used by French died in 1900. Also the British lost 70,000 camels because of their lack of knowledge about camels. Therefore the animals kept dying from overwork (Gauthier Pilters and Dagg, 1981).

2.1.3 Importance

Camels have become ahistorical part of the major nomadic civilizations inhabiting the hot dry zones of the northern hemisphere. A camel expresses the essential component of the culture and agriculture in the arid regions of the poor Saharan countries. It lives in wide arid and semiarid areas, which are not appropriate for crop production and less suitable for the rest of livestock (Ramet, 2001; Mirkena *et al.*, 2010). Therefore, in this part of the region camels are preferable to all other livestock in terms of food security (Ramet, 2001; Ahmad *et al.*, 2010). According to continuing land degradation and accelerating growth of human population, expectedly the importance of camel will be increasing. Camel breeding stands for a superior branch of animal husbandry. It provides people with resource of food of high calorific value (meat, milk and blood) and industry with useful raw materials, such as wool and leather (Baimukanov, 1989). Also camel faeces are utilized as a fuel. Owners collect annually 950 kilograms of droppings per adult animal in the desert steppes of central Asia. It burns with a low flame which lasts long time and the burning of the droppings produces just a little smoke so the women can cook easily even inside in the tent (Lensch, 1999).

In addition to significant calorific value camel milk has a high content of vitamin C, essential minerals (calcium, iron) and fat, moreover its proteins have a high digestibility. Asians claim the milk has unique curative properties therefore they use it as a medicine when undergoing digestive disorders or even tuberculosis. (Baimukanov, 1989; Gauthier Pilters and Dagg, 1981). It was also discovered that the special composition (a number of imunoglobulins, protective proteins and allergens) of camel milk improves allergic reactions. Significant results were achieved within food allergies leading often to anaphylactic reactions in children (Shabo *et al.*, 2005). A female of dromedary camel gives in average 3.5- 4.9 litres of milk daily at gestation. However well-fed camel is capable yield from10 to 15 litres of milk per day (Ahmad *et al.*, 2010). During the long draughts, it is about 1 litre less due to a seasonal influence. Some other noticeable factors that have impact on the amount and chemical composition of the milk are the stage of lactation, access to the pasture, number of calving, the condition of the pasture and the health both calf and mother. The milk production of individual female per lactation varies between 1,000 and 12,000 litres. The lactation curve resembles to bovine one, it only has a better persistence. The range of lactation length is between 8 and 18 months (Shaheen, 2001; Faye and Esenov, 2005) and the estimated camel milk production reached 2.9million tons of milk a world in 2011. For comparison the production of camel milk was only 1.7 million tons in 2001, which shows the growing interest of people in camel milk (FAO, 2014). One third of the milk is sucked by the calf whereas the two thirds are available for a human consumption or to be sold. The very important dairy product is "aaruul" characterized as a hard, dry, cubed cheese with good keeping qualities (Nori, 2010; Bekele *et al.* 2002).

Since the camel meat has comparable content of protein and fat to beef, it shows a huge potential in fight with world hunger. In general camel meat is said to be healthier as it contains more moisture, similar amount of protein and ash, but additionally it is lower in intramuscular fat to compare with other cattle (Abdelhadi *et al.*, 2012). The camel meat yield of the carcass produced in 2011 reached 2087 tons (FAO, 2014). The problem is that camels have to be kept life during the transport to meat-hunger nations because of limited possibility of refrigeration and preservation of the meat. Thus the carcass must be treated carefully so that it does not get threaten by salmonella (Ahmad *et al.*, 2010). Even though there is a way to extend shelf life of fresh meat by use of garlic or lactic acid bacteria (Bifidobacteria) which helps in preserving. (Kalalou, *et al.* 2004).Camels are usually bred under extensive system with poor access to valuable nutrition and slaughtering usually takes place in old individuals when their carrier in work, racing or milk production has finished. Dromedaries grow up to weight of 650 kg at 7-8 years and the carcass weight ranges between 125-400 kg (55% to 70%). Camel carcass comprises about 57% of muscle, 28% bones and 17% fat. The meat is similar in texture and taste to beef, but usually is higher. It contains 19% of protein and 3% of fat (Kadim, *et al.* 2008).

There is another significant potential that camels have and it is their thick and long coat that grows on Bactrian camels in the winter. For the wool are bred mainly 2 kinds of Mongolian Bactrian camels. They are the Galbin Gobi Ulan and the Khetsiin Khuren. Camels are the only large animal that is suitable for sustainable livestock husbandry in the South Gobi. Although camels account for only 2% of the Mongolian's livestock they generate around 10% of agricultural production. Every individual camel yields in average around 5 kg of wool a year. The hard hair taken from the chest, neck, knees and elbows stands for 26% of the annual yield and it has a fibre from 69 to 334 mm long. It is used by herders to product ropes and halters. Short wool is collected from the legs, the neck on its sides and body. The length of these fibres is from 50 to 157 mm and the use is for spinning yarn (Chapman, 1985). Mongolians annual wool production is higher than actual possible use of it. For example 3,000 tons of raw idle wool accumulated every year without being processed, in the 1970s. Even though the industry developed since the 1980s so the production of high-quality knitwear in the domestic markets is noticeable, the Bactrian camel breeders have to be aware of possible problems caused by market preference of cashmere goats, livestock widespread, dependency on demand of trade and most of all climate change that influences water sources and composition of plants in pastures .Despite the camel can feed on plants which are eatable neither for cattle nor for horses (Schmidt *et al.* 2010). In addition females reach puberty most of the time between 3-4 years of age, but they are bred at 5-6 years of age. Males reach puberty at approximately 3 years, however they are fully able of reproduction activity within age of 6-7 years (Al Eknah, 2000).

2.2 Adaptation of camels

The main differences between ruminants and the Camelidae is that the Camelidae have no horns or antlers, they have slightly different fore-stomachs known as compartments, and characteristic oval-shaped red blood cells in camels. Those cells can circulate even in thick blood and can significantly expand during rehydration (Faye and Esenov, 2005; Muctar, 1990). Average weight of camel calf is between 30 and 40 kilograms at birth and the normal weight of a year old calf should be between 150 and 180 kilograms. A camel weighing about 500 to 600 kilograms is considered as a mature and it becomes more less around age of 6 or 7 years. Bullocks are most of the time particularly heavier, often between 510 and 635 kilograms, whilst female’s weight balances between

470 and 510 kilograms. Maximum height of mature camel reaches 2.4 metres measured to the top of resting hump (PISC, 2006). Camels can reach to about 40 years in dependency on state of their teeth. Most of the time the teeth are after 30 years of age in such a bad condition that the animal can no longer pasture and consume feed. In addition valuable working live of camel is from 6 to 15 – 20years (Köhler-Rollefson *et al.*, 2001) and pregnancy duration in dromedary camel is on average 380 days (Sghiri and Driancourt, 1999).

2.2.1 Anatomical adaptation

2.2.1.1 Skeleton and musculature

Camels are large mammals characterized by the length of the arched neck helping them to reach the twigs and leaves in height 3.5 meters from the ground, and by the conical shape of the abdomen that creates a large surface area that improves heat transfer (FAO, 2001). Although the skeleton of camel looks massive, it is remarkably adjusted for slow and cumbersome movement due to elongated cervical vertebrae and the position of their elbow and knee joints that are very high situated on their legs. Camel spine represents the axis of camel's body and its shape is strongly curved to compare with other ruminants. The spine is composed of 7 cervical, 12 thoracic, 7 lumbar, 5 sacral and 18 caudal vertebrae. Length of the cervical spine represents almost one-third of the length of the spine as noticeable in Figure 2. Neck of a camel is strongly bent downward and upward curve again to the body and it is even longer than it is in horses. The chest is deep and narrow to allow an easy shift of the balance the shorten chest is composed of only 12 pairs of ribs compare to 18 ribs in horses (Fowler, 2011). These big ribs form a stable ribcage with low mobility. The thoracic section is narrow beside the abdominal part of chest which is wide spread. However, the loins are about one or two vertebrae longer than the horse ones. The bones in camel are called the same like in other ruminants however the shape or number of bones might differ. For instance radius bone of thoracic limb is much longer in camels whereas ulna is much shorter to compare with the cattle's one (Vernerová, 1990; Fowler, 2011). Worth mentioning is also a pelvic bone whose shape is remarkably rounded on account of missing bumps on the sacral bone and iliac bone. Visible at first glance is also a short distance between the hip joint and point of buttock. Therefore the muscles of pelvic bones are underdeveloped and camels become unsuitable as a draft animal. In general musculature of camel is thinner and weaker than horsy musculature. Camels have the most developed muscles of the neck, forelegs and shoulders. Distinction is noticeable in muscles of thigh, which are not fully connected to the muscular system however it functions nearly independently (Šáda and Šatava, 1987; Fowler, 2011). Another significant difference might be the centre of gravity that is placed more at the front of camel's body owing to the long neck together with overall robust and heavy front part of camel body. The result is a poor complex stability as well as specific movement of camels which differs from other animals due to varying static and dynamic arc in movement (Vernerová, 1990).

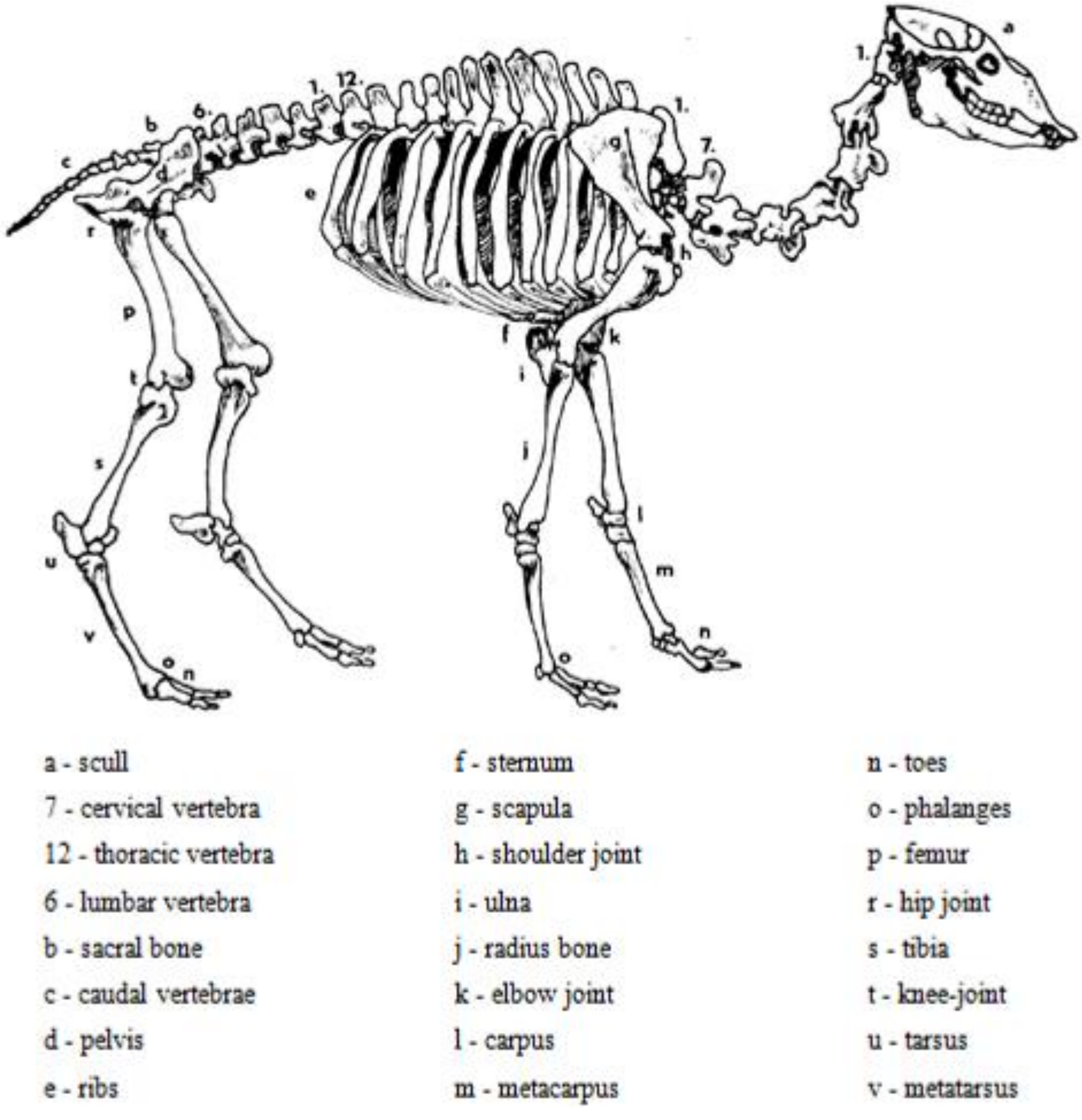

Figure 2. Dromedary skeleton

(Source: Vernerová E. 1990.Fyziologie a anatomie hospodářských zvířat: Doplněk k učebnici Biologické základy živočišné výroby. Prague: Vysokáškola zemědělská Praha. 102 p.).

2.2.1.2 Specifics of the head

Camels head is small in comparison with other mammals. Skull shape resembles a horse's skull with jutting zygotic arches and dorsal part of the skull divided into cranial and facial regions (Shahid and Kausar, 2005). On the top of the head camels have little erected ears which contain hairs that work as a filter preventing them from the sand getting inside (Gauthier Pilters and Dagg, 1981). The eyelashes are remarkably thick and long to protect the eye together with a skeletal postorbital bar. The eyes are well adapted to the excessive light and they can see very well either during the day or at night. In the daytime the retina is stroked by only a little amount of intense sunlight because the pupil receives a great protection from the fringed margins of the iris. The eyelids are sort of translucent to allow the animal to close their eyes when they need to continue walking in a sandstorm. The flow of lacrimal secretion is large and constant to prevent the corneal epithelium and conjunctiva from drying out. (Gauthier Pilters and Dagg, 1981). The snout of camel is ended by massive, short haired lips that are very flexible for movement which helps them select the right food. The cleft upper lip gained the advantage of selective movement of each half in different direction. Since camels are browsers, this adaptation becomes very handy when eating leaves from thorny trees and shrubs (Faye and Esenov, 2005; PISC, 2006). The oral cavity of camels is covered with mucosa which consists of hardened papillae directed toward the oesophagus. The essential role of the papillae is to prevent the chewed food from felling out from the oral cavity (Fowler, 2011). Also the nasal cavity is well adapted to the extreme environments of desert. Despite the head of camel is not of very big size, the nasal cavity is much longer in comparison to horses. Nevertheless it is visibly narrower owing to its adaptation to sand and dusty environment. Camel’s nostrils have little cavities that allow the inhaled air to moisten and the exhaled air to cool down which helps reducing water loos (Gauthier Pilters and Dagg, 1981). The nostrils look like two long slits with shape of wings and camel is being the only animal which gained the feature to close its nostrils to protect itself against sand and wind (Faye and Esenov, 2005).

2.2.1.3 Teeth characteristics

Teeth of camel are complete, although compare to ruminants it is different. Camels have three pairs of consecutive powerful teeth in the upper jaw. They remind of canines, but the only canines are the middle pair. While the first pair is formed by incisors, the third pair is formed by the front premolars. The incisor teeth are protruding forward and the upper incisors is actually placed instead of canine teeth (Köhler-Rollefson *et al.*, 2001; Ewoldt and Nagy, 2008). There are also less of the chewing teeth (two pairs of premolars and three pairs of molars). The lower jaw is composed by three pairs of incisors, couple of canines and two pairs of premolars. The dental formula of adult camel is following 1, 1, 2-3, 3 / 3, 1, 1 - 2, 3 = 30-34 teeth. While the lower molars have only two roots, the upper molars have four roots (Ewoldt and Nagy, 2008; Fowler, 2011). The baby camel has 22 deciduous (milk) teeth. We are able to determine the approximate age of the animal to the age of 9 years, according to the time of replacement and teeth wear intensity. Older camels are difficult to identify by the teeth therefore it is recommended to take in account other factors such as sexual maturity, skin texture or grey hair presence; when determining age of the individual (Köhler-Rollefson *et al.,* 2001). Usually camels older 5years can suffer from periostitis or osteitis of mandible often caused by root abscesses which spread along mandibular canal and can affect gastrointestinal or musculoskeletal system (Ewoldt and Nagy, 2008).

2.2.1.4 Humps and energy

Camels have one or two humps on the back attached to the trunk skeletal muscles through a sheet of thick and strong collagen fibres. The cranial hump in Bactrian camels is attached to the thoracic region by the trapezius muscle and rhomboid muscle (Endo *et al.*, 2000). Function of humps is to store fat that the animal mobilizes to meet energy demand during periods when they have lack of food and water. (Reece, 2009; Mirkena *et al.*, 2010).To compare with other camelids, llamas deposit most of their body fat in different characteristic regions such us shoulders, cranial ribs, briskets, inner thighs or perineum (Tibary and Terrel, 2008). However camels deposit most of body fat in their humps and abdomen. Both body compartments are composed from similar fatty acids. Humps of younger camels contain less total fatty acids and also age of animal has effect on fatty acid composition (Kadim, 2002). The two humps of the Bactrian camel are about 25 to 35 cm high. Their function is not, as it is often mistakenly assumed, to store water but to store energy. Nevertheless, there is none of bone constituents included in the hump. It is formed by solid strands of connective tissues and white adipose. After the fat conversion, the storage takes place exactly among these connective tissues (Vernerová, 1990; Fowler, 2011). Unlike the elastic hump of the dromedary, the two humps of the Bactrian camel are largely inflexible, so that they flop over to one side once all the fat reserves have been

depleted. The breakdown of fat always starts in the caudal hump. Each fatty hump contains around 25 to 35 kg of fat, which is equivalent to a calorie reserve of 250,000 to 350,000 kcal. The adipose tissue consists of cells capable to store lipids in cytoplasm. In other worlds, the size of these specific cells is dependent on the amount of intercellular fat. There were obvious changes in the size of camel's humps during rainy periods of the year. The size of humps increased in these periods (Faye, 2001; Reece, 2009). The appearance of the two humps (firm and full or flaccid) is an indicator of the nutritional state of camel.
Survey of Bengoumi et al. (2005) revealed distinctive changes in hump size in relation to level of feeding. Hump weight of overfed camels increased by 71% whilst weight of camels that were experimented underfeeding decreased by 41% as compared with the initial state of both groups (Bengoumi et al.,2005). The humps contain most of the body fat, except for the kidneys which embody an internal perirenal fat reserve (Faye, 2001). The tilt of the hump is characteristic for every single animal (Reece, 2009). The hump in adult Bactrian camels tend to skip from one side to another when it is in a flaccid state, particularly in old individuals, when the humps lose their fat, whereas the skin of the dromedary's hump is a bit more elastic, so that the hump easily shrinks in size when the animal loses fat during stress periods. (Gauthier Pilters and Dagg, 1981; Reece, 2009).

2.2.1.5 Skin properties

The elastic skin on the top of the hump as well as skin everywhere else on the body of camel is attached very tightly to the underlying hypodermic connective tissue which is largely fat-free to allow release of redundant body heat. The composition of the skin is similar to other livestock but it is more sensitive than in cattle. Another distinction of camel skin is reduced number of sweat glands. It is another smart adaptation to hot climates which restrict sweating and hence ensure economic water management (Nazifi and Gheisari, 1999). With the raise of thermal stress in cattle immediately increases evaporative adjustments such as panting or more efficient sweating which ensure optimal heat loss (Silanikove, 2000). Indeed, camels usually start sweating after the atmospheric temperature reaches 42°C when at rest. Despite this high temperature they do not sweat continuously (Nazifi and Gheisari, 1999). Further camels have massive skin glands on their back that secrete sticky mass, particularly in the mating season. This secretion smells very intensively to make sure the females register that the male is in rut. On the other hand female camels have udder located in pubis area as well as in cattle. The udder is separated into four quarters which each of them ends by milk nipple. On the surface of the udder is soft elastic skin, which is cover in soft hair only in winter, it loses the hair in spring (Yagil, 1982). In comparison with the one-humped camel, the Bactrian camel has longer and darker-coloured hair, shorter limbs and a more massive body, which are cold-adapted features. Function of long hair is to protect animals from rain and cold. Therefore camels start to moult the hair as soon as the warmer weather arrives within beginning of spring. During the summer hot conditions camels have almost no hair. Whereas the coat of dromedaries is composed of much shorter hair and it is most of the time coloured yellowish or resembling sand colour. The Bactrian camels can have different colours and shades from rare white or grey to more common straw coloured coat or dominant brown coat. Sex, location or colour shade of coat does not influence the length of hair in different species whilst both age and health conditions have impact on length and quality of camel coat (Iñiguez *et al.*, 2014).

2.2.1.6 Legs and calluses

At the end of camel's long and slender limbs they have no hoofs, but the divergent toes ending in nails spread nearly flat on the ground which is an adaptation for easy gait in desert environment (Komárek et al., 2001; Faye and Esenov, 2005). The padded soles of the feet widen on treading the ground. This structure of the feet facilitates walking through quick sands and soft snow but hinders movement on muddy and slippery soil. Another advantage is that unlike hoofed animals, camels do not trample a pasture, which is a great benefit for grasslands (Baimukanov, 1989). When a camel lies down on the ground, it uses special protective elements called calluses or horny pads to be seen in Figure 3. These important elements of camel's body were gained as adaptation feature for protection against the hot sand and stones in the desert environment. The sand can actually come up to 60-70°C in deserts during the hot summer months.

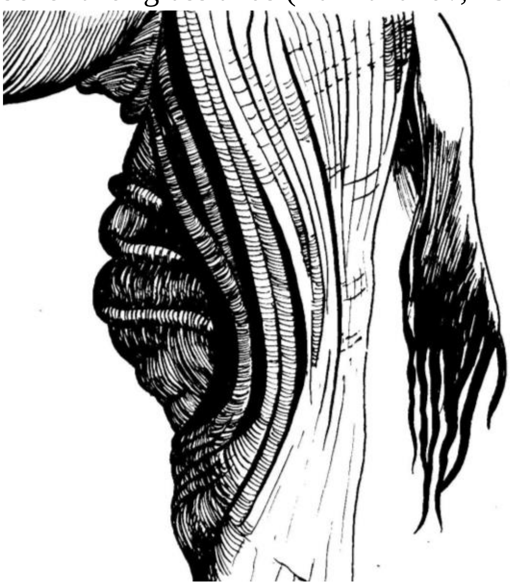

Figure 3. Protective callus on camel knee. *(Source: Vernerová E. 1990.Fyziologie a anatomie hospodářských zvířat: Doplněk k učebnici Biologické základy živočišné výroby. Prague: Vysokáškola zemědělská Praha. 102 p.).*

These peculiar calluses are placed on the knees, elbows, a chest and thigh joints to stifle and prevent from injuries when sleeping in the stony desert. The biggest horny pad is the one on the chest. Thickness of the hardened skin on the chest can reach even 10 or 15 centimetres and it covers all the area of breastbone. Dromedaries have the calluses a bit more developed than Bactrian camels. It is because of the warmer climate in places which dromedaries inhabit. The animal rests the most of body weight on chest horny pad when it is lying. It also hides all the legs from the sun beneath its body. As a protective behaviour camel do not kick out their back legs backwards like horses do, however they kick out the back legs forward like cattle do or slightly to the side. They are also able to kick one front leg straight forward and thus kick a man or other animal unexpectedly (Šáda and Šatava, 1987, Fowler, 2011).

2.2.1.7 Forestomachs

Particular differences have been found in between motility, histology and also ultrastructure of the epithelium in forestomach of ruminants and camelids. Although camels also ruminate they are not true ruminants, as they lack the four well defined stomachs of the ruminants (Engelhardt, 1994). To compare with the bovine's four compartments: the rumen, the reticulum, the omasum and HCl-secreting abomasum; the forestomach of Camelids is only formed by three different compartments (Figure 4). The first and very spacious compartment (Cl) contains of a cranial and a caudal sections. From there, the processed part of the food continuous into a smaller compartment (C2) where the food is divided to well-digested portions. Following third compartment (C3), an intestine-like organ tubular in shape was developed from C2. C3 is located at the right side of C1 and it continues in a small hind stomach, which produces HCl (Lechner Doll, 1995). The "abomasum" in camels is divided to four parts namely cardiac, pseudocardiac, pyloric and fundic parts. The cardiac and pseudocardiac parts occupy almost third-fourth of the organ (Raji, 2011). Unlike the ruminants that have the forestomach covered completely with a smooth, stratified squamous epithelium and no glandular cells, the forestomachs in camelids contain the cardiac glands reminiscent to the pig's cardiac glands (Engelhardt, 1994). Abdel-Magied and Taha (2003) describes in their histological study that the large gastric glands could indicate that, the stomach of camels is more likely used for chemical digestion than fermentative digestion in comparison with cattle (Abdel-Magied and Taha, 2003). Moreover camels may selectively retain in forestomach different feed particles in accordance with the digestibility of the plants. This prodigious mechanism together with impact of volume and fluid turnover plus forestomach motility enables camels to inhabit places with so rough grazing conditions (Engelhardt, 1994).

Ruminants *Camelids*

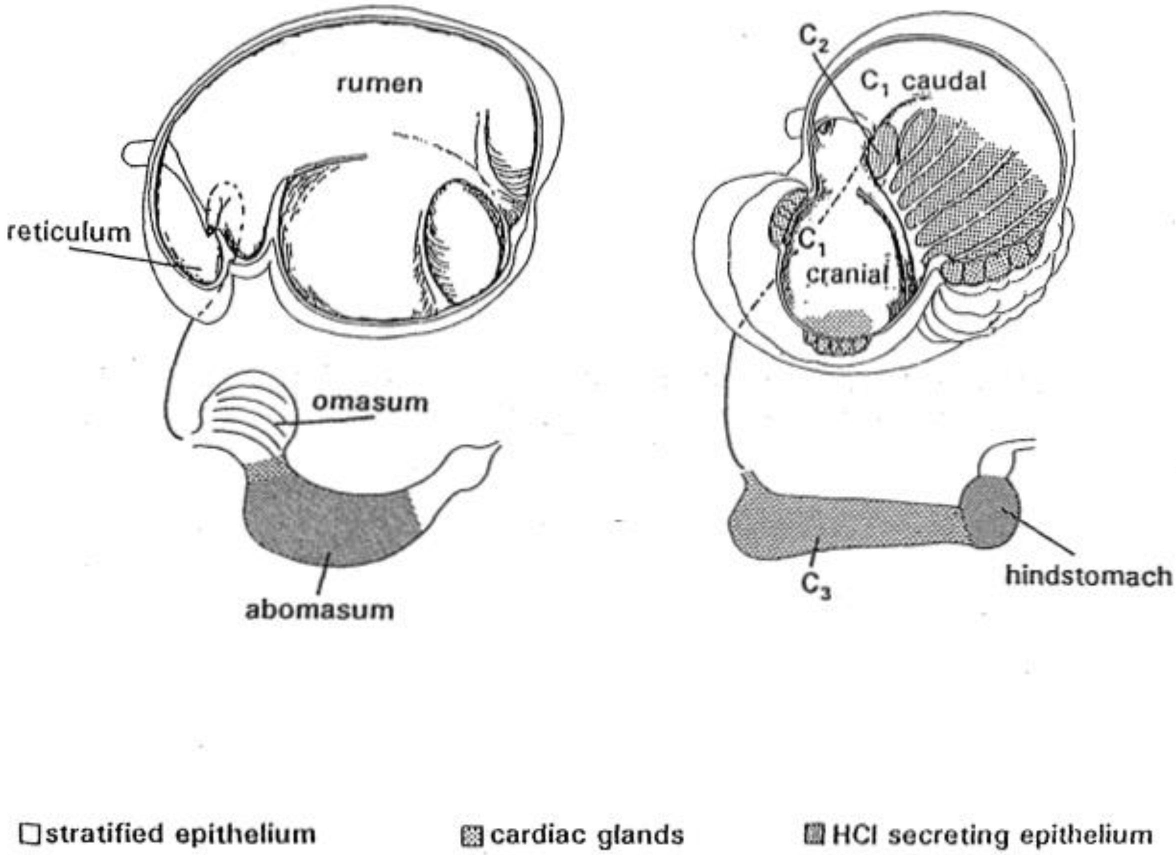

Figure 4. Differences between forestomach compartments in ruminants and camelids

(Source: Lechner Doll M, Engelhardt WV, Abbas AM, Mousa HM, Luciano L, Reale E. 1995. Particularities in forestomach anatomy, physiology and biochemistry of camelids compared to ruminants. Options Mediterraneennes 13. Zaragoza : CIHEAM, 19-32.)

2.2.2 Physiological adaptations

As we have earlier seen, there are many anatomical adaptations which the camel gained to survive in the desert; however there is a great deal of physiological adaptations without which a camel would not have a chance to survive in these conditions. It is suited to go for long periods without water, drink large amount of water in a very short time, it can increase core body temperature, and it pastures a wide range of plants including the ones with thorns and dry bushes. A camel can also adjust their behaviour to conserve the water (Schmidt-Nielsen, 1964; Achaaban *et al.*, 2000; Assad and and El-Sherif, 2002; Engelhardt *et al.*, 2006)

2.2.2.1 Feeding

The Bactrian camels of central Asia are kept as livestock in the severe desert steppes which gets the annual precipitation between 80 to 120 mm including snowing in the winter. The extremely continental climate brings on one harsh winter with temperatures going 40°C below zero whereas the summer temperatures can reach up to 55°C. Also the pastures in winter are covered with snow so there is only limited source of food (Baimukanov, 1989).Camels are dependent mostly on their surrounding environment and the vegetation which grows in those areas. They are given supplementary food by their owner only very rarely. However it was proved that under range conditions, concentrate supplements during pregnancy improves reproductive and productive parameters in camels. Birth weight of offspring whose mothers were fed with supplements reaches in average 30.3 kg versus 23.4 kg in offspring whose mother was not offered dietary supplementation during the perinatal period (Hammadi et al., 2001). Eventually, if camels are considered as important workers their owners should include a high level of leguminous roughages in camel diet, too. According to Gupta *et al.* (2012) particularly supplementation with groundnut haulms affects the speed of travel or power developed by camels. In general level of legume in camel diet influences biochemical parameters of blood as well as lactate. Appropriate diet has effects the physiological responses after work, especially pulse and respiratory rates (Gupta *et al.*, 2012).

On the other hand, even though the harsh environment where most of camels live does not offer many desert plants rich on nutritional requirements, camels can clearly survive due to very effective digestion of poor quality cellulose-rich forage (Engelhardt, 1994) Moreover, it is also proved that the low protein intake has less effect on liver function of camels as compared to sheep (Assad and El-Sherif, 2002). It might have what to do with specific lobation of camel’s liver. It is devided in five different lobes of various size and shape, unfortunately not exact function of each lobe has been discovered yet (Endo *et al.*, 2000). The effective digestion was developed through the retention time of digesta in the camel's forestomach which can be selectively prolonged as opposed to other ruminants. This ability became crucial segment of adaptation to harsh pasture conditions (Rutagwenda *et al.*, 1989). Nevertheless limited food intake does not meaningly influence volume of protein, glucose, lipids, cholesterol and triglycerides that were measured in plasma after food restriction for different period in various camels (Nabiela *et al.*, 1994; Assad and El-Sherif, 2002). There was only a noticeable however any crucial tendency to increase in lipids, especially cholesterol after food deprivation (Nabiela *et al.*, 1994). Although, further investigation on digestibility detected much efficient digestion of crude fibre and N-free extract in camels compared to sheep, digestion of crude protein was more effective in sheep and goats than in camels (Gihad *et al.*, 1989).

In fact camels do not necessarily demand a large variety of plant species in their diet however if there is an option they enjoy diversity for browsing. They are capable of aimed selection of more digestible plants. Camels always keep on moving while grazing which provides beneficial value which is that they never graze all of the vegetation accessible like goats do (Dörges *et al.*, 1992; El-Keblawy, 2009). Therefore camels are able to reach a distance 5 kilometres in 2.5 hours when they are browsing on the local vegetation. Quality of the vegetation does not seem to be crucial for camels. They usually bite the same kind of plant species only a few times and move to a new plant (Dörges *et al.*, 1992). Even though, they prefer mainly dicotyledonous plants that are of high quality and digestibility (Rutagwenda *et al.,* 1989). Survey in Kenya brought the information that camels are able to select adequate forages in the semi- arid rangelands to meet their mineral needs except for Cu and Zn. Over 80% of foraged species preferred by camels contained even higher than sufficient concentrations of Ca, P, Mg, K, Na, Fe and Co during both winter and summer season (Kuria *et al.*, 2004). Dörges *et al.* further describe in a study that took place in Australian Alice Springs that camels always searched for the freshest plants at first. Even though the plants included a high content of moisture or minerals, the camels would still move to another plant after a few bites. The area in the study covered 200 square kilometres and the observed camels were found to select 82% of all plant species available in that area. The same study also shows the preferences of camels. They only eat the grass primarily, when herbs, forbs or leaves of trees and shrubs were not available (Dörges *et al.*, 1992).

Nabiela *et al.* (1994) confirmed by their research that the captive camels promptly reduce intake of hay when they lose an access to drinking water. The purpose is to make a reservoir of large amount of water in the digestive system for upcoming case of dehydration. The explanation could be also a reduction of saliva flow which was noticed and may be the reason of reduction of hay intake (Lechner-Doll *et al.* 1994; Nabiela *et al.*, 1994). However Engelhardt *et al.* (2006) repeated the same experiment and found that camels after 11 days of water shortage hay intake reduced only by 9.6% of control (Engelhardt *et al.* 2006). Interestingly camels were found to have totally opposite preferences of feed and water intake to compare with sheep and goats. When both feed and water is offered to camels, they primarily start with drinking and then move to feeding, while goats and sheep eat before drinking. Also the total time spent eating was much longer in goats and sheep than in camels (Shaheen, 2000). This might be because of camel's forestomachs have more efficient digestibility in comparison with most ruminants. It is due to longer time of the feed retained in the forestomachs (Engelhardt, 1994).

Additional specifics were detected by Mengli *et al.* (2006) who observed the foraging behaviour of 10 domestic Bactrian camels in their study. The camels were the Alashanm Bactrian camel, which is one of four breeds of Bactrian camels living in the western part of Inner Mongolia. The foreging behaviour was dependent on *Haloxylon ammodendron* as it was the most common plant in the region. The composition of camel's diet was mostly of three herbaceous perennials, four shrubs and a few annual plants. The most preferred were *S. ammodendron* , *Z. xanthoxylon* , *C. latens* ,and *N. sibirica* from the shrubs; *A. mongolicum*, *Agriophyllum squarrosum* (83% of diet) and *S. collina* from the annual forbs or two perennial grasses *Psammochloa villosa* and *S. klemenzii*. However preference of *C. latens* was found only in spring and summer period while preference of *Allium mongolicum* was registered in summer and autumn. It appeared that camels prefer the annual forbs; however their growth is dependent on the weather and season (Mengli *et al.*, 2006). Camels are usually smart enough not to consume poisonous plants. However there are situations when food poisoning occurs. It is most of the time caused by their breeder who move the animals into a new grazing area and camels do not have experience of the locally growing plant species. Another explication for camel consuming poisonous plants could be resemblance of harmful plant to regularly consumed plant species or a great hunger because the camel did not have access to food for a long time. Such plants could be for instance *Buxus semper virens, Calotropis procera, Capparis tomentosa, Cassia occidentalis, Euphorbia tirucalli, Lantana indica, Nerium oleander* and surprisingly also *Sorghum bicolor* when the plat is young and contains cyanide. The poisoning is most of the time followed by different signs such us diarrhoea, vomiting, kicking of the belly, running in circles or foaming at the mouth (Köhler-Rollefson *et al.*, 2001).In addition,to assess the changes in feeding of individual animals or to evaluate the nutritive value of the specific pasture is recommended to monitor body condition of individual camels at least four times a year (before winter, middle of winter, spring and summer). The important changes should be evaluated from monitoring of general appearance, palpate over the ribs, locations of fat deposit and shape of the humps (Tibary and Terrel, 2008).

2.2.2.2 Water use

The water requirements of camels are directly dependant on age, body weight, exercise, temperature, humidity, pregnancy, disease, lactation but mostly on water content in the feed. Free ranging camels obtain all the necessary water from the plants they pasture on, thus when the plants do not supply sufficient amount of water, camels walk up to 60 kilometres to a waterhole every second or third day. Due to the exceptional tolerance camels have against dehydration, they can walk long distances without receiving water much longer than any other domesticated animal (PISC, 2006). It has a low rate of water loss due to several adaptation features. At first the low output of water via urine, secondly low respiratory rate and further the low content of water in camel faces. Not to become dehydrated camels also save water by avoiding the sun and by mobilization of vasopressin, this keeps water in their body. The camel has a very efficient kidneys producing concentrated urine. Under certain circumstances, it may be withheld so that the urea was not synthesized to protein by the microbial flora in the rumen. However the osmolality of body liquids still increases and water deficit in the body is further signalized to another homeostatic mechanism, the temperature regulation. These contradictory regulations are driven by the hypothalamus (McKinley *et al.*, 2008). Camels have a highly efficient system which helps them to balance the required amount of nitrogen through recycling urea and selective intake of desert plants in dependence on the nitrogen content. Another specific readjustment to reduce the water loss is a distinctive kidney structure which minimalizes the removal of urea. This urea is subsequently assimilated by the stomach microflora into the cavities to ensure synthesis of protein (Farid, 1989; Ramet, 2001).

Even during the hottest days of crossing the Sahara Desert, Dr. Knut Schmidt-Nielsen never observed camels to breathe with open mouth or panting. That shows the capability of inventive management of body liquids (Schmidt-Nielsen, 1964). Frequency of drinking is dependent on the age of individual, the humidity, the outside temperature, the working exertion and as well the amount and nutritional and water content of the food they have access to. Therefore any general rules about water use and water requirements of camels are purposeless. For sure there is a general rule about water content in blood plasma. Camels should reach drinking water before volume of blood plasma decreases and mammary blood flow begins to be disturbed (Shaheen, 2001).Taking in consideration impact of dehydration on volume of electrolytes, especially Na^+ and K^+ in blood plasma. Achaaban *et al.* (2000) found out in their work that the concentration of Na^+ in plasma increased in all examined camels during dehydration whilst concentration of K^+ decreased steadily. The same experimental work states other outstanding result which is the dependence of concentration of both previously mentioned electrolytes on environmental conditions. Other essential findings were reported by Kataria *et al.* (2003) who describe changes in body fluids in different body compartments of camel's body in relation with dehydration. On twelfth day of dehydration was the biggest loss of body water in interstitial fluid (ISF) declining by 36.4% decline whilst after six days of water deprivation was maximal decline (-18.4%) in intercellular fluid volume (ICF) during winter. 2 hours after rehydration the recoveries were minimal in ICF (+34.6) comparably with red cell volume (RCV), plasma volume (PV) and blood volume (BV) which also had the highest percent recovery (+48.6%). On the contrary during the summer the declines were maximal and equal in volumes of ICF and ISF with difference in results after 4 and 8 there days of water deprivation (29% and 40%). Volumes of PV, BV and RCV were recovered first in summer as well as in winter (Kataria *et al.*, 2003). Further results on water management by Achaaban *et al.* (2000) revealed that the concentration of Na^+ in urea increased in both environments the first week of water deprivation. However the second week of dehydration levels of Na^+ changed significantly. In Rabat where there was by the time mild humid summer climate the level of the salt in urea stayed elevated even the second week whereas the level of Na^+ decreased rapidly in the hot and dry summer environment of Tadla in Morocco. Moreover the concentrations of K^+ and Na^+ in urea differed in dependency on the outside environment. Particularly the daily Na^+ output at Rabat increased by 100% at the mild climate while it decreased by 80% at the hot climate (Achaaban *et al.*, 2000).

Considerably, Schmidt - Nielsen *et al.* (1956) mention in their work the ability of camel not to drink water for 1-2 months during the rainy season. Gauthier Pilters and Dagg (1981) state that dromedary camels living in the Sahara Desert do not drink for six or seven months during the cool months, even that they are offered water. This is due to the moisture of the plants which fulfil their water requirement. When exposed to extremely hot conditions they can drink water only every eight to ten days (Lensch, 1999). An average size adult dromedary camel requires 30 - 40litres of water per day (PISC, 2006) however it is capable of drinking up to 100 litres at a time (Engelhardt *et al.*, 2006; Gauthier Pilters and Dagg, 1981). Although they do not store all the water in their stomach but it is chemically transformed into fat and subsequently stored in their humps (Schmidt - Nielsen *et al.*1956; Tibary and Terrel, 2008). Bekele (2010) registered during his experimental study considerable results. He sorted out a group of camels in different categories. One of them had access to water once a day, the second was allowed to drink after 4 days in the desert, third group was watered after 8 days and the last one did not have drinking water accessible for 16 days. First group drank on daily average 17 ± 5 litres /day. The second group refilled the water deficit by drinking on average 47 ± 5 litres of water on the four days when water was available. The third group drank 72 ± 5 litres after 8days and the most dehydrated animals drank 88 ± 5 litres after 16 days being without drinking water accessible. The total water intakes were 254 ± 25 L in group1, 195 ± 16 L in group 2, 140 ± 12 L in group 3 and 88 ± 5 L in the thirstiest camels (Bekele, 2010). To compare with research of Nabiela *et al.* (1994) when the camels did not have drinking water accessible for 10 days their body weight decreased at 8%. At the moment they could have drank again they drunk 35 litres of water the first day and 8 litres of water the second day. After those 10 days with no water, the measurements showed expressive changes in blood plasma in comparison with food restriction which did not lead to any significant changes in blood plasma. Volume of total lipids, mainly cholesterol and fatty acids increased whereas a volume of insulin and glucose was not influenced by dehydration (Nabiela *et al.*, 1994). It seems like that camels respond to dehydration in a similar way like other ruminants do, however dehydration in camels appears in16 days compare to its occurrence after 4 days in goats (Bekele, 2010).

Another exceptional adaptive readjustment which the camel gained is the ability to survive loss of essential quantity of water, precisely the loss over a quarter of live weight of the animal through dehydration. The human and most of other mammals would pass away if they had lost of water even 15% of their body weight. (Baimukov, 1989; Lensch, 1999). Only to compare, Ayoub and Saleh (1998) states that the ruminants can withstand noticeably bigger losses of water, namely 18% in cattle, 20% in sheep, 25% in camels and more than 40% in desert black Bedouin goats. Water loss through evaporative cooling is minimalized by controlled change of their body temperature in the range of 6°C (Schmidt-Nielsen, 1964; Bekele, 2010).

The camel can also regulate and reduce the urinary and faecal excretion when experiencing a water deprivation. It means they produce even drier droppings and very concentrated urine. (Schmidt-Nielsen, 1964). Availability of only 1% saline water increases intake of freely accessible water about one third compare to fresh tap water. After consumption of saline water the camel's faeces contained more water whereas the water content of urine was smaller than after drinking tap water (Farid, 1989). Furthermore it was proved that camels are not affected by saline load or nutrient shortage as much as sheep (Assad and El-Sherif, 2002). It was found out in an experimental study of Assad and El-Sherif (2002) in which a few sheep and camels had a limited access to water and fed for 40 days. Live body weight of camels reduced by 1.9% while the live body weight of sheep decreased by 8.4%. Camels have to balance the input and output of water and sodium ions to keep the volume of extracellular fluid in average limits (Assad and El-Sherif, 2002). Camels are able to regulate intake of salt by reducing the amount of saline water intake in comparison with sheep which did not changed their drinking customs significantly after they had been offered the saline water (Assad and El-Sherif, 2002). In addition, water losses via urine in camels are regulated by antidiuretic hormone vasopressin, which is released from the neurohypophysis (Gauthier Pilters and Dagg, 1981). Also Lechner-Doll *et al.* (1994) discovered in their research that the rehydration of camel leads to reasonable drop of the osmolality in forestomach fluid as well as remarkable growth of forestomach fluid volume. Fan efficient thirst mechanism acts an important role in the homeostatic control of fluid balance. The concentration of the solute in body fluid increases when the animals do not have access to drinking water and they become dehydrated and as a consequence the volumes of intracellular and extracellular fluid are reduced. The extracellular fluid volume (including the blood) decreases owing to osmotic action in case the animal do not get sufficient amount of sodium from their food (Andersson, 1971). Bogner *et al.* (1998) explain the extreme low content of water in erythrocytes of camel (1.1–1.3 g water/g dry mass) by a comparatively high osmotic unresponsive erythrocyte water fraction. They state that the variation of haemoglobin sequences in camels could be gained in natural selection process as prevention against osmotic dehydration in desert environments. The Kidneys of camel contain specific cells producing hormone renin which initiates reactions that lead to secretion of aldosterone, the sodium-retaining hormone which is formed in the adrenal cortex. Sodium depletion motivates the animals to search for a source of salt to ingest (Schmidt- Nielsen, 1964).

Despite of high salinity of water in arid and semi-arid areas which can be often detrimental for the livestock, camels actually require higher content of salt in their diet. That could have been a result of evolutionary adaptations due to high water content of ions such as Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, $SO4^{2-}$or $HCO3^{-}$ in these arid and semi-arid zones that camels inhabit (Whitehead, 2000). Lensch (1999) states in his thesis that especially the Bactrian camels have specific dietary requirements on amount of salt they have to ingest. Estimations were made between 60 and 120 grams of salt per day. Camels obtain the salt particularly from brackish waters and saline plants of the desert steppes. The Mongolians golden rule warns you that a camel must receive an exceptional supply of salt when they are required to walk long distances, nevertheless the grazing camels should not be offered salt *ad libitum* as camels are known to eat a lot more salt than they actually need (Achaaban *et al.*, 2000). Even though camels refuse any other food in case there are saline plants freely accessible. Therefore drinking of the same amount of water to their body weight loss does not have to mean the animal has already recovered. Because deficiency of salt mobilizes aldosterone, it could take much longer to refill salt than water (Lensch, 1999; Achaaban *et al.*, 2000).

The dietary requirements are the component of the adaptive properties of camel to life in the desert steppes. If the animals do not have a proper source of minerals they become slender and weak. Even their energy storing humps reduce to one third of their normal size and the camels are unable to carry people or heavy loads on long tracks (Lensch, 1999). Despite the saline plants are very low in cellulose, they contain apart of valuable sodium also high volume of necessary protein (Achaaban *et al.*, 2000). In 1883 camels carrying 350 kilograms of packs on their back overcame the distance of 447 kilometres in 16 days they were indulged a day to rest followed by 240 more kilometres to cope with. All of this previously mentioned was managed by the camels with no source of water in extremely hot conditions. Moreover, working camels are able to journey distances such as 1000 kilometres without drinking water. In addition, the volume of water which camel drinks is not to store up for future uses, but to refill the liquids already lost through urine, droppings and evaporation (Gauthier Pilters and Dagg, 1981).

2.2.2.3 Thermoregulation

Despite of sophisticated anatomical and physiological mechanisms that camels obtained to withstand the extreme conditions which they are exposed to; even camel can suffer from sunstroke. The heat exhaustion is basically interpreted as inefficiency of brain to control cooling process of the body in conditions of high ambient temperatures often combined with high humidity (Köhler-Rollefson *et al.*, 2001; Mitchell *et al.* 2002). The preoptic part of the anterior hypothalamus compiles and evaluates information from thermo receptors throughout the body. Hyperthermia emerges in case of thermoregulatory malfunction due to incapability of body to handle an elevated thermal burden (Nagy DW, 2008). However there are more consequences except for the heat and strong sun rays that take the blame. It is combination of heat stress and also deficiency of minerals and vitamins in the feeding (Köhler-Rollefson *et al.*, 2001). On the other hand Shaheen (2001) describes that the rectal temperature in camels decreased during food and water deprivation. Explanation might be given as a strategy of metabolism due to lower metabolic activity in camels during food and water deprivation, followed by body temperature reduction (Shaheen, 2001) However when heat stress arises in camels, it is recommended to focus on cooling of ventral body surface first as there appears to be the best evaporative cooling spot (Nagy DW, 2008).

Autonomic thermoregulatory adaptations of camels are very closely related to water use systems. Their ability to lower evaporation during the summer is due to the possibility of regulating their body temperature. Most of homoeothermic animals have to balance heat which they produce and heat loss to keep the necessary body temperature. Therefore camels should not be seen exactly as homoeothermic animal as their body temperature changes depending on ambient temperature (Schmidt-Nielsen, 1964). The regulation of temperatures is controlled by nervous feed-back mechanisms to be found in periphery of the hypothalamic region in the brain. Hypothalamus also consists of special neurons which are responsible for responding to changes in body temperature (McKinley *et al.* 2008). Resistance of camel's metabolism to deflections of temperatures is also supported by Heat shock protein 70 (Hsp70) which provides protection from heat and extreme factors on the cellular and organismal basis. In general structure of hsp70cluster is comparable with the organization of it in other mammals. Except for that this vital hsp 70 gene is transcribed in various camel tissues such us lymphocytes and heart muscle tissue even under casual conditions to compare with the other mammals where there is the vital gene to be found only after heat shock. Both constitutive and differential synthesis of hsp70 family proteins have been seen in cells of different origin in camels by 2D electrophoresis. It might partly explain the ability of camel cells to withstand such extreme conditions (Garbuz *et al.*, 2011). A camel stores the heat inside the body and allows a significant rise of the body temperature instead of keeping their body temperature constant, which would lead to use of the scarce water in evaporation. (Schmidt - Nielsen et al, 1956) Surplus heat accumulated during the hot day or after hard physical effort is later lost by conduction, convection or radiation when the animal rests or when the ambient temperature fall down at night (Ramet, 2001; Mitchell *et al.* 2002).

The rectal temperature in morning is low and increases gradually all the day, which reduces evaporating (Schmidt-Nielsen, 1964; Bekele, 2010). Interestingly the body temperature of red kangaroos is also higher at night and decreases rapidly early morning until ambient temperatures and radiant heat start to increase (Maloney *et al.*, 2011).During the winters the rectal temperature vary as much as 2 or 3°C, whereas during the summer observation reached the variations in body temperatures of up to 6°C (Grigg Gordon *et al.*, 2009; Schmidt-Nielsen, 1964). Different periods of year also directly influence concentrations of cholesterol triglyceride, lipoproteins and total lipids that are all presented in higher levels in winter. It is due to thermal stress that is camel experiencing in both extreme conditions severe cold environment in winter or heats tress in hot summer (Nazifi and Gheisari, 1999). Similar impact of seasons on body compartments composition in camels, body fluid volume is also higher during dehydration in winter than during dehydration experienced by camel during the winter (Kataria *et al.*, 2003). The rectal temperature which Dr. Knut Schmidt- Nielsen had always measured in camels came up to maximum 40.6°C, which might be the critical limit beyond which the animal does not permit the body temperature to increase (Schmidt-Nielsen, 1964) unless it suffers from any disease at the moment. But for instance when a camels is infected by *Bacillus cerus* that causes serious haemorrhagic disease, the body of camel experiences long days going fever up to 41°C. Unfortunately 50% of the infected animals stop feeding and ruminating and dies after 3 to 7 days (Köhler-Rollefson *et al.*, 2001).

Coming back to the extreme changes in body temperature in camel, the morning body temperature never went lover than 34°C even if the weather was cold or it was raining (Baimukov, 1989). On the other hand Bekele (2010) found out during his experiment that the lowest rectal temperature reached minimum 32.7°C and maximum registered temperature was 40°C. Only to compare, the core body temperature of the savannah elephant *(Loxodonta africana)* is 36.2°C with amplitude of 0.49°C which is lower than in much smaller ungulates inhabiting the same environment (Kinahan *et al.* 2007).Although there is a significant difference between the body temperature variations when comparing camels dehydrated for 16 days with camels that were watered daily. The average daily variation of rectal temperature was 3.8°C in camels experiencing dehydration for 16 days, whilst the temperature in daily watered camels was measured as 3.2°C. The rapid variations between morning and evening temperatures reaching as much as 5-6°C were registered only in several occasions during the experiment Bekele (2010).

In the same study was also proved that camels deliberately regulate their respiratory rate, which might have conjunction with thermoregulatory functions. The animals without access to drinking water were measured the average diurnal respiratory rate 6.5 ± 0.2 breaths/min in the first 8 days however it decreased to average diurnal 5.1 ± 0.2 breaths/min between days 9 – 16 (Bekele, 2010). In addition, availability of drinking water could have impact on behaviour of camels in relation to thermoregulation, too. Maloney *et al.* (2005) describe that free-living wildebeest *(Connochaetes gnou)* changed frequency of parallel and perpendicular in dependency on whether the water was freely available at the moment or not. Black wildebeest probably uses autonomic thermoregulatory mechanism when the water is available, whereas it switches to behavioural thermoregulatory mechanism when water is not available. This behavioural adjustment might possibly be used by camels, too. It means that the animal orients parallel in relation to sunlight more often as ambient temperature and solar radiations grow, on the other side the frequency of the animal's posture perpendicular decreases if ambient temperature lower or shade is available. Supposedly, black wildebeests mediate the changes via the skin temperature and react with deliberate change of their body axis orientation to the sun (Maloney *et al.*, 2005). The present study will determine whether camels adopted such a behavioural pattern.

Another part of thermoregulatory systems in camels is the fur which works as a shield against the solar radiation as well as the coat for insulating from the harsh conditions in high altitudes of Mongolian mountains. In the winter the fur grows very thick to protect them. However camels loose it in the spring when a new thinner fur begins to grow. Although the spring coat is much thinner it still has quite a thickness and it plays an essential role in the protection from the sun (Iñiguez *et al.*, 2014). The body parts which are the most exposed to sun rays, for example back or head are covered with thick hair and it is never lost entirely (Schmidt-Nielsen, 1964). The surface of the animal body in the context of solar radiation brings into discussion another topic and thus the influence of radiant heat on production of metabolic heat by the animal. Walsberg *et al.* (1997) claim that the endotherms are capable of balancing the metabolic heat production in dependency on incident solar radiance and wind speed. Particularly their experimental work with Siberian hamster *(Phodopus sungorus)* showed that its metabolic heat production declined by 27-41% according to intensity of irradiance and wind speed (Walsberg *et al.*, 1997).

Another remarkable finding brought Grigg Gordon *et al.* (2009) as he discovered that the bulls of dromedary camels in rut have the average daily body temperature lower than the bulls in no rut. The average of minimum body temperatures in males differs by 0.6°C comparing to other times. Unlike at first studies on adaptive heterothermy (Schmidt-Nielsen), which were made in captive camels, this one was measured in free-ranging dromedary camels and took place in the Great Sandy Desert in Central Australia. The study shows that camels by lowering the heat stress by 0.6°C can extend the time of fights between rival males in rut. Because the actual winner of the fight gains a whole harem of females, to start up a new day with a cooler body temperature becomes an invaluable advantage which finally leads to the success of reproduction. This study shows another pattern of heterothermy in camels, however this time it is not a strategy of water saving as the drinking water was all the time freely available from salty lakes (Grigg Gordon et al, 2009).

2.2.3 Behavioural adaptations

Physiological adaptation in camels could be seen as the most inventive and the most essential mechanisms for survival of camels in the harsh environment of the mountains and desert however the importance of adaptations which influence the way of thinking and other behaviour cannot be so easily disregarded. Behavioural adjustments are equally vital for survival and reproduction (Hetem *et al.*, 2011). Camels in general are good-tempered and very patient animals. However males in rut might become very aggressive and dangerous for other members of the same herd or even for people. Cases of death in camels have occurred in past, when males in rut were fighting for the female. The signs of upcoming rut in bulls are for instance creation of foam around the mouth, gnashing of teeth, wide stance of back legs or a sharp increase in size of the testicles. The bulls also possess ascent gland in the area of scruff of the neck, which secretes malodorous secretions when a camel is in mating season (Vernerová, 1990; Fowler, 2011). In addition dromedary camels have a special organ in their mouth which is often mistaken for a tongue. They display this 30 to 40 centimetres long organ which is called dulaa or palate, only when the males are in rutting to attract females (Fowler, 2011). Female camels do not change their regular customs or behavioural conducts as much as males do. Occurrence of anxious or restless behaviour might be noticeable. A female also demonstrate sexual interest by jumping on other females which are lying on the ground or by adjusting its own body position as at mating when the male is passing by. In addition, camels became seasonal breeders due to semi- arid and arid conditions. Active ovaries and pregnancy have been found in camel females most of the time between October and May, which specify the breeding season. In contrast the period between June and October shows only a little frequency of active ovaries or pregnancy in females. Even the aromatase activity of granulosa cells and follicular maturation were found to reduce at this non-breeding stage (Sghiri and Driancourt, 1999). Regions in which camels are native have extremely high ambient temperatures during the day and extremely cold at night. However camels adapted to these cruel places show a remarkable behavioural readjustment when the daily temperatures reach very high during the day time. On these hot days, dromedary camels deliberately form crowds standing closely next to each other. Aim of this ingenious behavioural adjustment is to cover the ground with the shade and thus reduce the reflection of heat from the ground (Bekele, 2010). Moreover camels might deliberately change their body posture in relation to the sun rays to regulate heat exchange. This finding was actually one of aims of the present study. Bohorórquez- Alonso *et al.* (2011) analysed the same hypothesis on lizards, particularly *Gallotia galloti* in different localities and structural habitats. They proved that more lizards oriented perpendicular or parallel towards the sun rays in comparison with oblique orientations. Clearly perpendicular body orientation to the sun enhances the proportion of body surface exposed to solar radiation. On the other hand, orientation parallel in relation to sunlight decreases the animal's surface receiving solar radiation (Bohorórquez- Alonso *et al.*, 2011). Experiments of similar context have been done on different ungulates such us impala, eland, blue wildebeest and black wildebeest to prove that even mammals are capable of managing their body temperature through the deliberate thermoregulatory behaviour (Maloney *et al.*, 2005; Hetem *et al.*, 2011). Maloney *et al.* (2005) state that the black wildebeests *(Connochaetes gnou)* supposedly perceive changes in their body temperature via effect of incident solar radiation on their skin temperature. The wildebeest would absorb 30% less radiant heat as a result of parallel body orientation to when exposed to the sun to compare with perpendicular body orientation to the sun for the whole day. However it is necessary to take into consideration also wind speed, ambient dry- bulb temperature and coat of the individual animal which provides them with an efficient insolation (Maloney *et al.*, 2005). In contrast, the body axis orientation in *Gallotia galloti* did not show significant differences between orientation parallel and perpendicular in relation to sun rays (Bohorórquez- Alonso *et al.*, 2011), while the solar orientation behaviour in black wildebeest was found to be well developed as adaptation to regulate the radiant heat in the severe environment, which is by temperature effect a little comparable to habitat of camels (Maloney *et al.*, 2005).

Figure 5. Bactrian camel oriented parallel to incident solar radiation ***(Source: photo by author).***

Also Hetem *et al.* (2011) investigated thermoregulation of ruminants in terms of body axis orientation and solar radiation. The animal species chosen for the study were three African ruminants, namely impala, eland and blue wildebeest. This study confirmed the ability of some ungulates to preferentially orient their body orientation in relation to the sun rays as mentioned above. These three African ruminants all preferred perpendicular orientation to the sun in cold winter but on the contrary, preference of parallel orientation was proved in all three ungulates during the hot summer (Hetem *et al.*, 2011). However the influence of wind on metabolic heat production should be taken to consideration. For example Walsberg and Wolf (1995) found out that the change of wind speed from 0.5 metres per second to 4.0 metres per second leaded to 10-13% reduction of energy gained from radiant heat in squirrels (*Spermophilus lateralis* and *Spermophilus saturates*). Authors of the same study also determined possible effect of coat colouring on received radiant heat. However in the end they reported that no significant differences were found between these two differently coloured squirrels in relation to solar incident radiation (Walsberg and Wolf, 1995). Besides the influence of solar radiation on body orientation of these ruminants Hetem *et al.* (2011) as well investigated if there are any preferences of northerly orientation in these three species as it was mentioned in previous studies devoted to magnetic alignment in different species of ungulates. For instance Begall *et al.* (2008) state that some large mammals are able of magneto-reception and use it as beneficial for saving metabolic energy. As well Muheim *et al.* (2006) found that mice are capable of goal-directed magnetic compass orientation based on the perception geomagnetic field. Begall *et al.* (2008) found out that grazing and resting domestic cattle, roe deer and red deer orient their body axes position mostly in north-south direction which could be explained as intentional adjustment of their body position in direction of field lines of magnetic field of the Earth (Begall *et al.*, 2008). The other way round Hetem *et al.* (2011) revealed that none of the three analysed species preferred northerly alignment of their body axis. More specifically both eland and impala oriented within ach compass arc for comparable period of time whilst blue wildebeest revealed preferential use of north-westerly orientation. Results of the study further show that on sunny days with only a little breeze, about 60% of examined ungulates preferred perpendicular or parallel body axis alignment to the incident solar radiation dependant on the season, which demonstrates connexion with energy saving maintained by the animal itself. For example a small impala managed to save up 16% of its metabolic energy through this thermoregulatory behaviour (Hetem *et al.*, 2011).

According to research of Mengli *et al.* (2006) camels are foraging the least in winter and they spent the greatest time by foraging in spring. Despite there was no difference between walking and movement time in winter, spring and autumn; they spent significantly longer period by walking in summer. Camels spent less time resting in summer and spring to compare with winter and autumn. Hedi and Khemais (1990) examined camel's activity in spring and pointed out that the camels spent 29 % of the time eating, 39 % ruminating, and 32 % resting. Although 97 % of feeding was observed in daytime, 55.6% of ruminating occurred nocturnally as well as 55 % of resting activity (Hedi and Khemais, 1990). However, feed deprivation and drinking too much saline water have suppressive effect on the diurnal activity of camels, the influence of feet shortage is even bigger than in sheep (Assad and El-Sherif, 2002). The absolute time of rumination throughout the seasons was longer in autumn than during spring and summer months. Rumination time during the day in the field was comparable among seasons while in the enclosure during the night time rumination was more often in autumn than in any other season. Mengli *et al.* (2006) found that just about 14% of the absolute time of ruminating happened in day-time. The frequency of feeding was lower in autumn, higher in summer and very comparable in winter and spring. The frequency of defecation and urination was lower in winter in comparison with summer or autumn (Mengli *et al.* 2006).

3 Materials and methods

3.1 Materials

The literature review was based on scientific articles found by searching for specific keywords. The information on the specific topic was accessible from university web databases such as the Thompson Reuters ® (ISI) Web of Science. The necessary quantitative data on productions etc. were available in databases of international organizations such as the United Nations, the Bretton Woods's institutions or international research institutes and universities, such as database Science Direct, Web of Knowledge or FAOSTAT.

3.2 Methods

The practical part of the thesis was based on scan sampling method (Altman, 1974, Maloney et al. 2005 a Hetem et al. 2011) implemented on the Bactrian camels (*Camelus bactrianus*) bred in captivity of zoological gardens in Prague and Usti nad Labem in the Czech Republic. The scan sampling method consisted in recording of behaviour and compass orientation changes of each animal from the herd.

3.2.1 Identification of animals

Before beginning the actual observations, it is necessary to recognize individual animals observed in the herd. Particularly the two humped camels can be relatively easily recognized from each other. They are distinguished by differences between shapes and sizes of their humps. Also the humps might be bending to different sides. The differences in the face, position of ears and the physical structure of their whole body are crucial in the summer time. In time beyond the summer I noticed differences in the length, colour and quality of the coat.

3.2.2 Actual observation

The herd of camels examined in Prague consisted of 4 females (3-20 years old) and a single male which was 11 years old (Table 1), whereas the herd evaluated in Usti nad Labem consisted of 5 females (10-24 years old) and a single male which was 2 years old (Table 2).

Table 1. Characteristics of camels in the zoological garden in Prague. *(Source: Zoo Praha).*

	date of birth	place of birth	father	mother	member of herd since	sex	age
Andy	29.1.1993	Givskud	100603	100106	15.1.1994	0,1	25
Jepe	20.4.2002	Aalborg			28.11.2003	1,0	20
Jolanda	9.3.1997	Artis	M87015	M93066	24.7.1998	0,1	12
Lee	2.6.1998	Brno			24.6.1999	0,1	10
Sophia	24.3.2010	Liberec	Claudius	Shakira	2011	0,1	12

Table 2. Characteristicof camels in the zoological garden in Ústí nad Labem.
(Source: Pavel Král, Zoo Usti n.L.).

	date of birth	place of birth	father	mother	member of herd since	Sex	age
Lenka	20.3.1989	Ostrava			15.2.1991	0,1	25
Fatima	9.8.1993	Usti n. L.	Kraken	Fay	9.8.1993	0,1	20
Salma	2001	Rusko			4.9.2007	0,1	12
Kuma	2003	Rusko			28.4.2006	0,1	10
Kara	2003	Rusko			28.4.2006	0,1	12
Sahbi	22.3.2011	Erfurt			28.2.2012	1,0	3

As shown in Figure 5 the sites where the camel herds were located in both zoological gardens offered freely accessible drinking water and a barn providing shade if needed. Individuals from the herd were observed simultaneously, possibly in three consecutive days from 9 am until 17 pm in three different seasons. First period of measurements in zoological gardens were made in June and July, whereas second period was August and September and the third one was October and November. The subject of the observation was to examine every member of a camel herd.

Body axis orientation of each camel relative to incident solar radiation (long axis of body parallel, perpendicular or oblique to the sun) was recorded as well as the direction each individual was facing according to compass orientation that was classified into eight 45° arcs relative to magnetic north (Maloney *et al.* 2006). Behavioural changes were classified into ten specific categories based on Miková (2004).Subsequently the changes in behaviour were recorded into previously prepared tables at 10 min intervals (Altman, 1974). The selected categories were lying, standing, movement, feeding, drinking, excretion, stable, hygiene, social manner and other conduct. The information about dry-bulb temperature (°C) was collected from the local weather station and it was also measured by the portable thermometer at the place of observation.. Photographic documentation was taken by the digital camera Canon PowerShot SX20 IS. The research can be commenced after the successful completion of animal identification. Location with a good overview of the whole surface of the enclosure must be chosen as a base for observation.

3.2.3 Data analysis

Further, the data of individuals were statistically evaluated using filters for specific categories of obtained scans and different statistic tests. The analysis of body axis orientation preferences relative to the sun were also done in dependency on the dry-bulb temperature. Therefore the temperatures were divided into 3 categories: dry-bulb temperature less than 10°C, temperatures 10-19°C and finally temperatures more than 20°C. The relations between solar radiation and body axis orientation of camels were tested using Pearson's chi-squared test however the data used in this test had to be filtered only by behavioural categories “lying” and “standing”. Data used in this specific graph of distribution were also filtered for only “sunny” and “partly cloudy” scans. Those filters were selected to prevent results from interference by feed and water supply location, distraction by visitors or distraction by other animals on results.

For analysis of body alignment in dependency on magnetoreception were used both statistic methods: Kruskal-Wallis test and Pearson's chi-squared test. According to methodology of Begall *et al.* (2008) were in this part of analysis used only data of behavioural category “lying”. It was due to possible effects of feed and water supply location, distraction by visitors or distraction by other animals on results. As follows the data analysis, hypothesis about adaptation of camels to extreme conditions was assessed according to the research.

4 Results and discussion

Whereas the bibliographic research revealed a range of unbelievable adaptations of the camel to survive in ruthless conditions of its natural habitat, the field research pointed out some important findings to compare with previous scientific studies devoted to other animal species. Together eighteen days precisely 144 hours of data were collected during present research. Nine camels from two Czech zoological gardens provided us with 4750 scan samples that were taken every 10 minutes 8 hours per day. Solar radiation intensity, dry-bulb temperature and the weather in general changed within different seasons. Therefore the data had to be filtered in analysis so that it did not influence the result according to methodology of separate aims of the field research. As well the fact that the orientation of animals is perhaps influenced by wind speed should be taken into account. Maloney *et al.* (2005) state that dependant on wind speed the black wildebeest thermoregulatory behaviour would be influenced only in case the wind speed would be very high. On the other hand Bohorórquez- Alonso *et al.* (2011) mentioned in their studies that body alignment of *Gallotia galloti* lizards reflects most possibly a compromise between solar radiation demands due to thermoregulation but secondly social communication. As well this object might be taken to consideration, because camels have been frequently seen orient their bodies next to each other in a way so they could see the animal next to them. Walsberg and Wolf (1995) found out that suddenly increased wind speed by 3.5 metres per second reduced by 10-13% energy which would squirrels (*Spermophilus lateralis* and *Spermophilus saturates*) gained from solar radiant heat.

4.1 Magnetic alignment in camels

Despite a few recent studies claim that some mammals are due to their terrific evolutionary adaptation capable of magnetoreceptory behaviour. For example Muheim *et al.* (2006) found mice to have strong unimodal orientation in the magnetic field direction. Although alignment of body axes in observed camels did not deviate significantly to any of cardinal directions. There were no significant preferences towards north or any other cardinal point found in lying camels as to be seen in Figure 6. Whilst Begall *et al.* (2008) found roe deer and cattle adopting magnetoreception and therefore intentionally adjusting their body axis to north-south orientation the most often; we only found camels to orient the most towards west, however the frequency of facing west was not any statistically significant and nearly the same as frequency of northerly orientation.

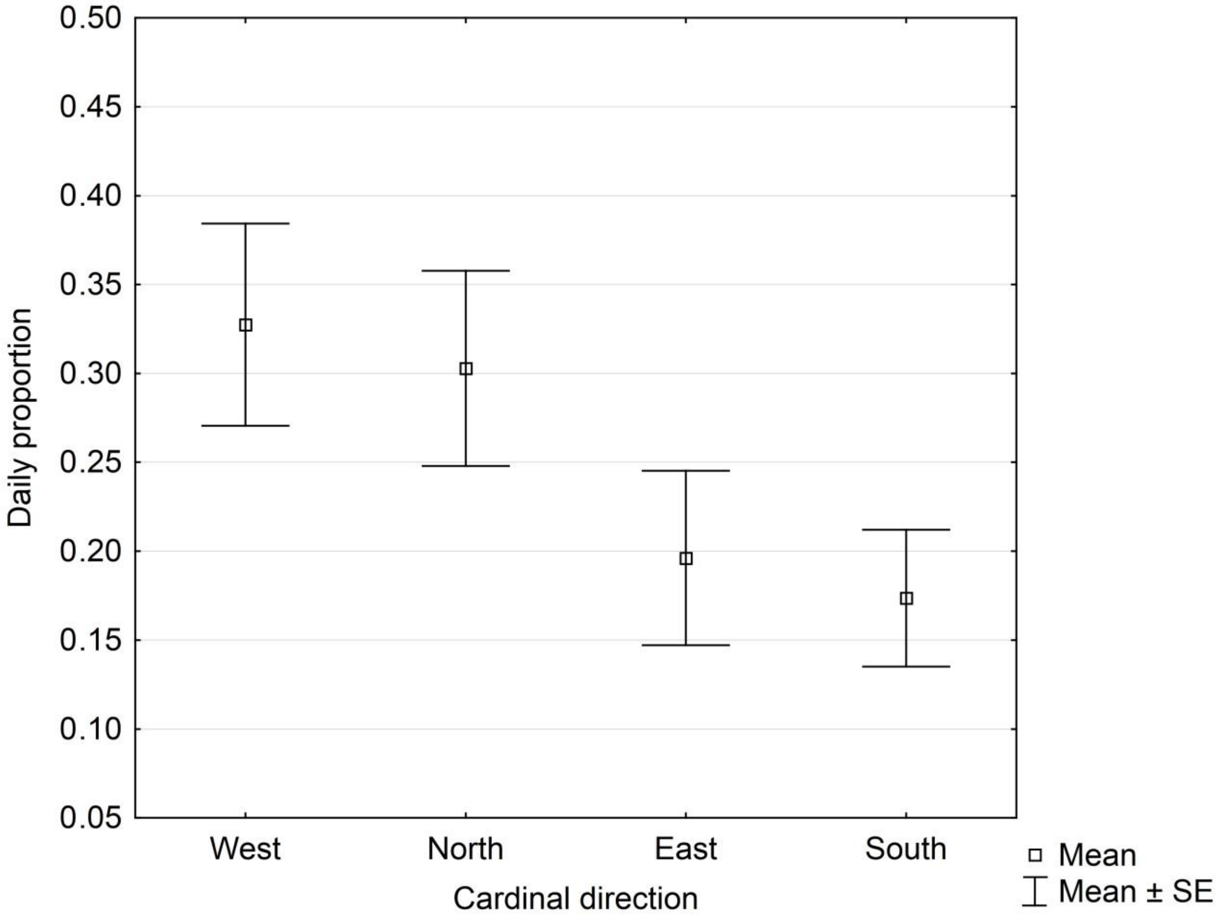

Figure 6. Distribution of body axis alignment in camels relative to each of cardinal points. (Kruskal-Wallis test: H (3, N= 72) =7.033652 p =0.0708).

Although significant differences were found between the two zoological gardens (Pearson's chi-squared test: 152.840, DOF = 3, p < 0.0001). Despite the camels in Prague zoo orientate more often north- south direction when lying, the camels in Usti nad Labem were found to be lying the most often in west-east direction. However those preferences might be influenced by terrain of site where camels are placed in Usti nad Labem as the whole site is located uphill in quite a steep terrain. We also suspect that the magnetic alignment preference in camels is affected by preferences of camels towards alignment of body axis in relation to the sun as mentioned in study of Hetem *et al.* (2011) which did not detected any preferences to orient north-south in eland, neither wildebeest, nor impala.

4.2 *Body axis alignment relative to solar radiation*

In this analysis were detected some remarkable findings according to previously conducted studies devoted to various animal species in relation to thermoregulatory behaviour (Maloney *et al.*, 2005; Hetem *et al.*, 2011). General distribution of camel orientation in relation to sunrays is to be seen in Figure 7.

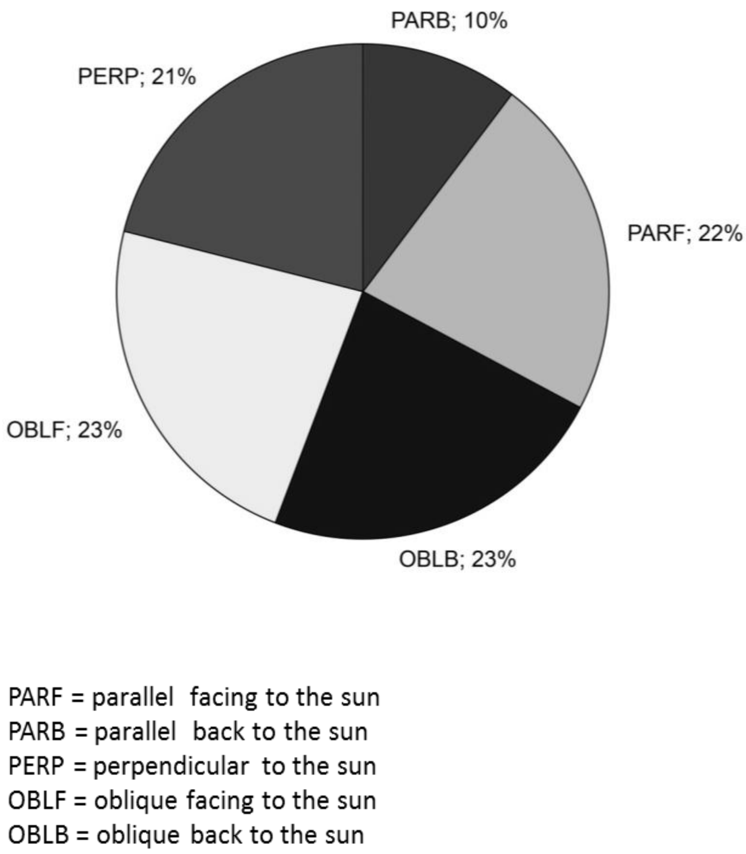

Figure 7. Proportions of camel body axis orientation relative to solar radiation.

However the graph in Figure 8 compares three different ranges of temperatures. In this case were revealed significant differences in body axis alignment in camels relative to the sun (Pearson's chi-squared test: 54.0007, DOF = 4, $p < 0.0001$). Ambient temperature had an influence on the orientation of camels to the sun. On the other hand Figure 9 shows frequency of parallel alignment was significantly numerous in higher temperatures but only in zoological garden in Usti nad Labem ($F (2.852) = 9.8485$, $p < 0.0001$). Nevertheless, another Pearson's chi-squared test (5.70980, DOF = 2, p = 0.057562) did not prove any statistically significant differences in distribution of solar orientation between the two zoological gardens.

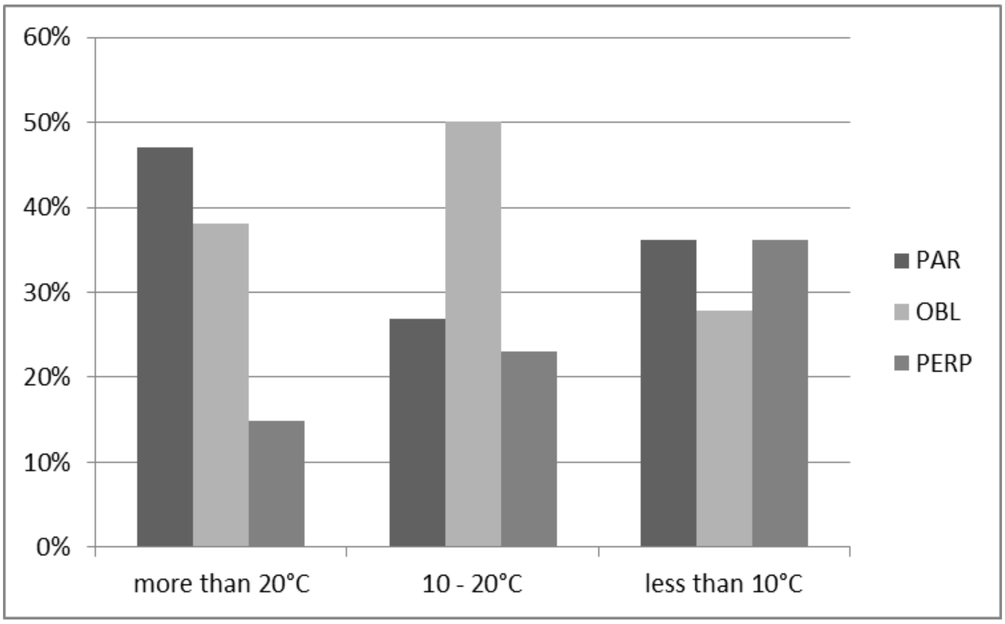

Figure 8. Proportions of camel body axis orientation relative to solar radiation in dependency on ambient temperature. (Pearson's chi-squared test: 54.0007, DOF = 4, p <0.0001).

The comparison of observed and expected frequencies (Figure 8.) showed the following trend: camels oriented more often parallel towards the sun during higher ambient temperatures (over 20 °C); more often perpendicular or oblique in temperate temperatures; and more often perpendicular in cold temperature (under 10 °C). This confirms results of Maloney *et al.* (2005) and Hetem *et al.* (2011) which state that black wildebeest, impala, eland and blue wildebeest preferentially orientate parallel towards the sun during warm summer and perpendicular towards sun rays in winter. Whereas perpendicular body orientation to the sun enhances the proportion of body surface receiving solar radiation, orientation parallel in relation to the sun rays decreases amount of received solar radiation (Bohorórquez- Alonso *et al.,* 2011). On the other hand Walsberg and Wolf (1995) determined possible effect of coat colouring on received radiant heat which could represent a negative impact on result. Also Walsberg and Wolf (1995) mentioned influence of wind on results of field research. Nevertheless, Hetem *et al.*, 2011 state in their work that data from days with little wind show that more than 60% of impalas, wildebeests and elands oriented their body position reflecting energy saving strategies, which concur our results as 47% of camels aligned their bodies parallel to solar radiation in direct sunlight when the ambient temperatures reached over 20°C. However I believe that particularly the wind speed, shadeless environment and limited access to drinking water might have effect on results of the field work. Therefore when the field research would be repeated in natural habitat of mountains or desert plains the results might vary.

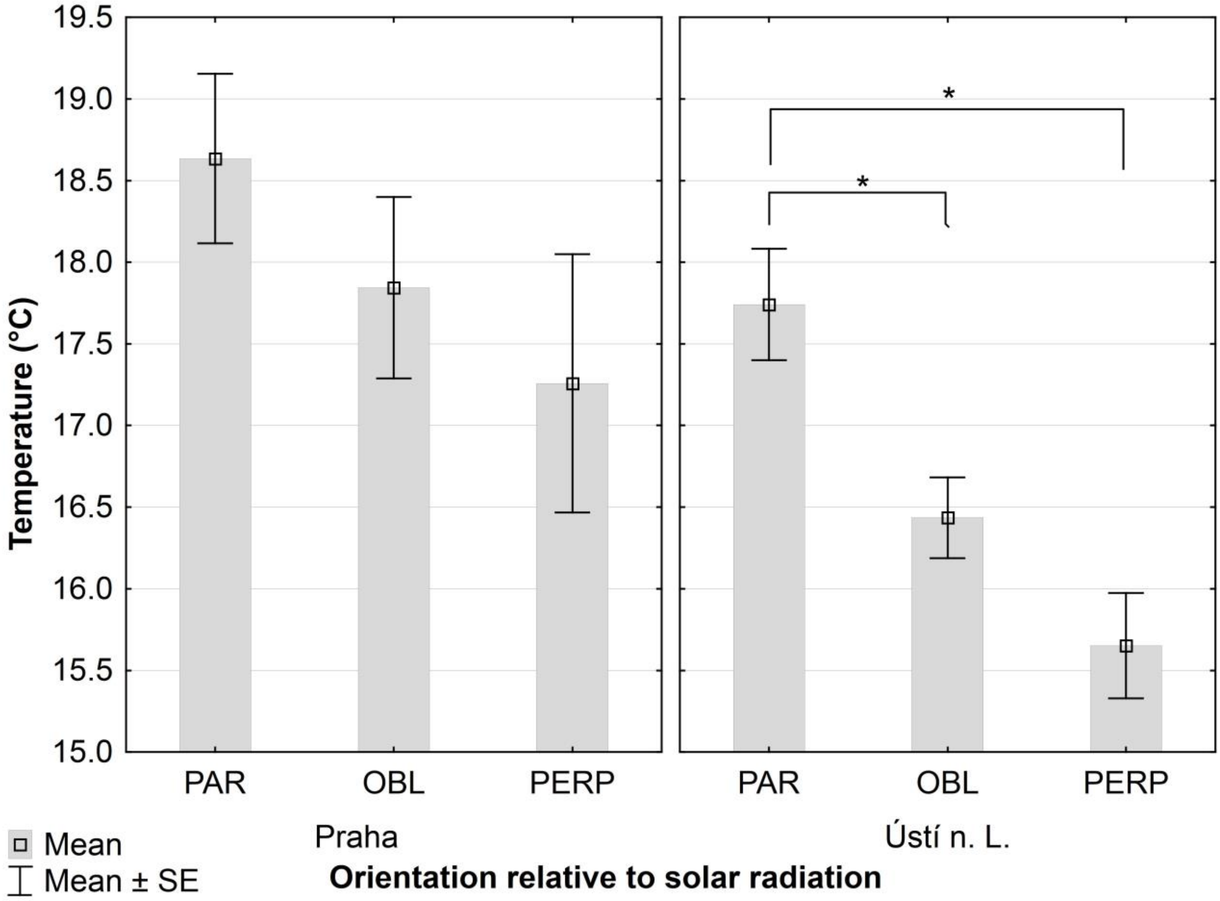

Figure 9. Differences between two zoological gardens in proportions of camel body axis orientation relative to solar radiation in dependency on ambient temperature. In Prague zoo the orientation was not proven to be dependent on temperature (F (2.408) = 1.1378, p = 0.3215) however body alignment of camels in Usti nad Labem was dependant on ambient temperature (F (2.852) = 9.8485, p < 0.0001).

4.3 Behavioural changes relative to ambient temperature

Analysis by Pearson's chi-squared test in Figure 10 demonstrates that there are statistically significant differences between overall behavioural pattern in both camel herds observed in zoological garden in Prague and Usti nad Labem (Pearson's chi-squared test : 97.2765, DOF=9, p < 0.0001). As noticeable in ethological graph camels in Usti nad Labem were often standing and tended to express social interactions more frequently whilst camels in Prague zoo spent most of time lying and feeding. Camels in Prague had an option to hide in stable when the ambient temperatures went low; however it seemed they would move inside the stable only when there was feeding accessible so it is discussable if these scans from stable bring any importance. The social interactions might have been due to a young male who have come to herd in Usti nad Labem recently. Therefore the daily activity of females could be affected. On contrary, the camel herd in Prague contains of one animal less and the herd is generally calmer which explains why there was observed less social interactions between animals. Those social interactions observed between camels were for instance biting another animal to their legs, jumping on another animal (often female onto other females) or licking body parts of other camels. In this specific analysis were used only scans obtained from healthy animals. As there were two old animals with healthy issues that would affect frequency of lying in Prague zoo and one animal of similar conditions in Usti nad Labem. In general, time that camels spent lying is comparable to blue wildebeest which spent lying 22% of their time during observations of Hetem *et al.* (2011). On the other hand Hedi and Khemais (1990) claims that camels spend 14.4% of day-time resting which would be similar to the proportion of camels in Usti nad Labem.

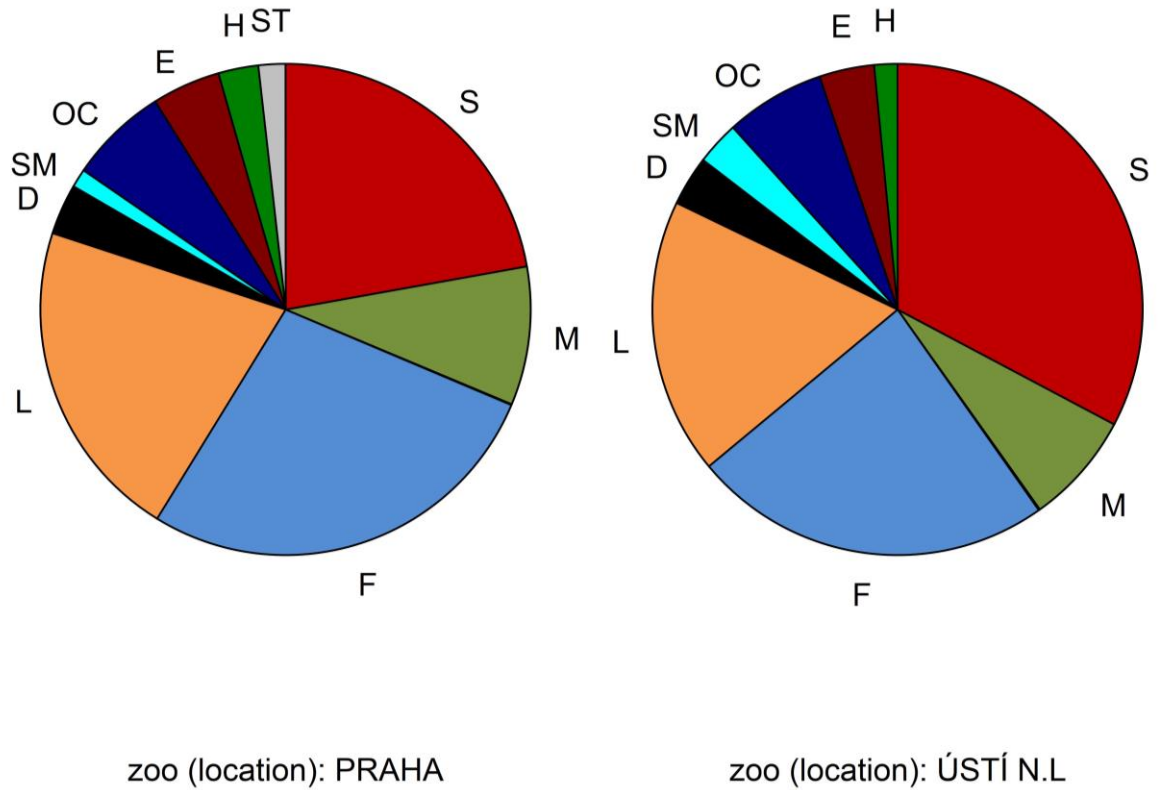

Figure 10. Differences between proportions of behavioural categories relative to ambient temperature in two zoological gardens. (L = lying, S = standing, M = movement, F = feeding, D = drinking, E = excretion, ST = stable, H = hygiene, SM = social manner, OC = other conduct).

5 Conclussion

Bibliographic research enabled us to detect a range of unique adaptations that the camel gained during evolution to survive in severe conditions of its natural habitat. From the morphological adaptations must be mentioned the very specific calluses on their legs and chest which prevent the camel from burns by the hot sand in desert, further humps which act as a storage of energy, very thick and long eyelashes together with camel's translucent eyelids guarantee the best possible protection against dust and sand. Such a protective function has as well thick hair in the ears and nostrils which can be selectively closed. Compare to other ruminates that inhabit the same localities camels have also much longer neck that allows them browsing for leaves and branches at a height of 3.5 meters. Also their cleft upper lip brings an advantage when feeding as each half of it can move in different direction and therefore enable camel to eat leaves from thorny trees and shrubs. Besides vegetation with thorns camels can utilize also dry vegetation and saltbush which other ungulates avoid. This ability has what to do with the camel's specific forestomachs as well as camel's well adapted water use system. Camels can go long weeks without access to drinking water and they are able to subsequently drink up to 100 litres of water in a short time. Those animals can further control water loss via faeces, urine but also evaporation. Ability to changes body temperature (34-40 °C) allows camels to accumulate heat in the body under extreme temperature and store it until the external temperature lower at night. Thermoregulation is also supported by “Heat shock protein 70” which protects camels against extreme factors on the cellular and organismal basis.

However autonomic thermoregulatory adaptations in camels might be very closely related to remarkable behavioural readjustment of different ungulates. Present study pointed out some important findings in comparison with previous scientific At first, the field research showed that camels did not preferentially align northerly or in any other cardinal direction which perhaps reveals that camels have not adapted to magnetoreception in comparison with roe deer and cattle that were found to be adapted in this way. Further in relation to thermoregulatory behaviour, one of the more significant findings to emerge from this study is that camels were found to orient more often parallel relative to solar radiation during higher ambient temperatures (over 20 °C); more often perpendicular or oblique in temperate temperatures; and more often perpendicular in cold temperatures (under 10 °C). Those results of field research prove a theory that camels adapted their behaviour in context of solar radiation and ambient temperatures. According to fact that alignment of body axis parallel towards the solar radiation minimizes the animal's surface exposed to the sun whilst perpendicular body axis orientation increases the proportion of body surface receiving solar radiation. An ethological observation revealed that camels in Usti nad Labem were often standing and tended to express social interactions more frequently, on the other hand, camels in Prague zoo spent most of time lying and feeding.

The study has gone some way towards enhancing our understanding of camel behaviour in relation to magnetoreception, ambient temperatures and solar radiation. Although the study has successfully demonstrated that camels do intentionally change their body position in relation to the sun, it had certain limitations in terms of weather conditions, times of observation, number of animals or shade seeking effects on results. Future research should therefore concentrate on the investigation of such thermoregulatory behaviour of camels. However it is suggested to undertake the research in conditions that are more closely to natural habitat of camels.

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