Egyptian J. Camel Sc., 2, No.2, 63-72 (2024)

Climate Change and Camels: Exploring Adaptations to Harsh Conditions

Ashour, G[1]., Kh. A. El-Bahrawy[2], S. M. Abdel-Rahman*[3]
[1] Animal Production Dep., Faculty of Agriculture, Cairo University, Egypt
[2] Animal and Poultry Physiology Dep., Desert Res. Center, Egypt
[3] Animal Production Research Institute, Agricultural Research Center, Egypt
* Corresponding author: Samah M. Abdel-Rahman
Email: samah.abdelrahman@yahoo.com

ABSTRACT

Dromedary camels "ship of the desert" have physiological features that make them more tolerant to harsh environmental conditions. During heat stress, they can minimize water loss via their digestive and urinary systems, besides their ability to conserve water via rumen. Moreover, thermoregulation and blood indicators are among the factors that give camels to be superior to the other ruminant's animals in living and producing healthy products (milk and meat) in the desert. In addition, morphological characteristics of camels, such as small heads and short hairs in the ear, enable the camels to filter air in the sandy environment. Camels have eyes with long lashes to protect the eyes from sand. Beside that, the long legs of camels are helping them to adapt to desert environments. This review discusses all these features in detail. With emphasis on the need to develop management in camel breeding that will reflect on improving camel productivity.

Keywords: Camels, physiological indicators, blood, kidney, rumen, morphology.

INTRODUCTION

Camels are God miracle on the earth, because they have unique morphological and physiological features that allow them to withstand harsh environmental stressors.

Climate change is one of serious threats during last decades and started to affect human, agriculture and animal production sectors, thus altering economic status. The main reason of these changes is human activity and methane produced from digestive tract of ruminants which caused elevation in earth temperature, sea level and salinity level in water and lands (Al Jassim and Sejian, 2015**)**. In recent years, there has been a great interest in studying the impact of climate changes on the productive performance of different farm animals, but camels have not received this much attention despite their distinction over other animals in terms of their tolerance to heat stress waves and their superior adaptability (Al Jassim and Sejian, 2015).

In 1950s, Schmidt – Nielsen cleared the ability of camels to change their body core temperature in response to ambient temperature. In normal conditions (with heat stress absence), their body temperature fluctuations are 2°C. Whilst, these daily fluctuations reach to 6°C when dehydration combined with heat stress (Zari and Al-Hazmi, 1993).

Dehydration occurs when there is a disturbance in body fluid balance in which more fluid is lost from the body than is absorbed, which in turn results in a reduction in circulating blood volume. The excessive loss of water and the failure of water intake are the principal cause of dehydration (Swenson and Reece, 1993). However, the physiological features of camels help them to drink every 10 days during heat stress conditions and can stand with the dehydration (Gaughan, 2011).

Therefore, all the morphological and physiological features that help camels to adapt the harsh environmental conditions will be discussed deeply in this review.

Camel's physiological mechanisms to adapt with desert conditions

1- Minimizing water loss:

Camel has the ability to reduce water loss during dehydration and heat stress, and both digestive and urinary systems are responsible for this ability (Mulu and Assen, 2018). The amount of loss water in camels is lower than other ruminant species. For example, camels lose about 1.3 liter / day through feces, while cattle lose 20-40 liter / day via feces (Mulu and Assen, 2018). Moreover, Gaughan (2011) cleared that; the amount of water turnover in camels is lower than in sheep (38-76 and 76-196 ml/kg/day, respectively). Their ability to tolerate water loss reached to 30% of their body weight, while other ruminants can tolerate only 10-12% of body weight. Camels can bear living without water for 14 days according to Elkhawad (1992). In other studies, camels can survive for 6-8 days without water (Schmidt-Nielsen, 1997 & Oujad and Kamal, 2009). This difference in authors' results may be attributed to the environmental condition and the availability of green fodder. After a prolonged exposure to water deprivation, camels can drink large quantities of water which reach to one-third of their body weight. Irwin (2010) found that camels can drink 110 liters in 10 minutes, this is considering a large amount and may affect the blood concentrations. So, this amount of water is stored in their gut for 24 h to prevent blood dilution (Willmer et al., 2006).

Therefore, camel surpasses other ruminants in their ability to withstand desert conditions and can live for long period without water due to their ability to conserve water via rumen and kidney. Camel's rumen anatomy differs from other ruminants, because it contains water sacs (water cells). These cells can store large water quantitates; represent 20% of total body weight (Mulu and Assen, 2018). In Saudi Arabia, Alloch (2016) collected 12 Camel's rumen from adult male camels aged between 3 - 5 years old to study rumen anatomy. The author found that rumen consists of two sacs; dorsal and ventral water cells (Photo,1). Both are represented 30% of the rumen size and they are divided into; cranioventral caudodorsal and caudoventral sacs, which differ in structure and shape from other rumen parts. They are working as water champers that keep water clean and away from digested feed. However, if camel exposed to dehydrations for long period, this may harm their gastrointestinal tract. Ali et al. (2019) studied deeply the influence of dehydration for 20 days on gastric mucosa of male camels aged between 4-5 years old.

Photo (1). Cranioventral and caudoventral water sacs in a camel's rumen Alloch (2016)

They recorded significant increase in malondialdehyde (MDA, the main product of lipid peroxidation and protein destruction) and elevated levels of antioxidant buffers (glutathione, GSH and catalase enzyme, CAT). In contrast to GSH and CAT, the activity of superoxide dismutase (SOD) was at low level in abomasum mucosal tissue. These results indicate that a prolonged dehydration causes oxidative stress in camel gastric mucosa, and the antioxidant buffers do not follow the same pattern during oxidative stress (Crawford et al., 2000). Moreover, the authors reported extrinsic apoptosis pathway in camel gastric mucosa through binding tumor necrosis factor-alpha (TNFα) and cytokine with their receptors (on cell surface), leading to form a complex to activate the initiator apoptotic marker caspase 8, that is important to activate the effectors (caspase 3 and 7). They also measured level of caspase 9 and p-53 protein and they did not record any significant differences between dehydrated, control and rehydrated groups. According to their results, the extrinsic pathway is involved in abomasum mucosa apoptosis not the intrinsic one. They concluded that, exposes camel to dehydration for long time (20 days) caused oxidative stress and elevation of apoptosis level in gastric mucosa.

Kidney has a vital role in concentrated urine through elevating its osmolality (Abdalla, 2020). The ability to concentrate urine is depending on four elements as follows:

2- relative medulla thickness (7.89 according to Abdalla and Abdalla, 1979), the medulla is considered as indicator of loops and henle length (both are important in concentrating urine) and as a scale for assessment of the ability of kidneys to conserve water. Renal medulla in camels has a well-developed structure and its percentage to cortex (Photo. 2) is 4:1 according to Mulu and Assen (2018).

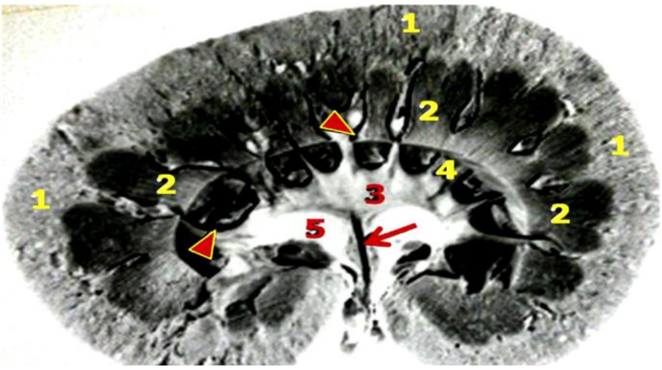

Photo (2). 1- cortex; 2- renal pyramids converging to form the excised renal crest; 3- main cavity of renal pelvis; 4-walls of collateral recesses; 5- normal fat padding around the ureter, Abdalla (2020)

3- Structure of renal pelvis, that in close association with renal medulla in concentrating urine (Abdalla, 2020). This structure is facilitating urea cycling, thus boosting osmotic concentration in renal medulla.
4- 3- The cortex tubules, that occupy about 67.12% of the cortex and responsible for reabsorption about 7/8ths of water entered to glomer cells (Abdalla, 2020).
5- 4- The release of antidiuretic hormone (ADH), when blood osmolality elevated, it sends a signal to hypothalamus to release ADH hormone, to help in concentrating more urine (Abdalla, 2020). Therefore, the superior camel abilities in concentrating urine allow them to conserve more water during dehydration. In addition, it enables camels to feed on halophytes and drinking salty water, contain more than 3 % of NaCl (Mulu and Assen, 2018). Recently, Ali et al. (2020) assumed to be one of the first studies that investigated deeply the impact of prolonged dehydration period (for 20 days) and subsequent rehydration (free water for 72h.) on camel kidney. They determined markers of pro-inflammatory interleukins (cytokines, IL-1ß, IL-6 and IL-18), oxidative stress (MDA, GSH, SOD and CAT) and apoptosis in both renal medulla and cortex. They reported discriminated elevation in the level of IL -18 in renal cortex and lower one in the medulla, in both dehydrated and rehydrated camel groups. Therefore, renal cortex consider the source of IL -18 production. The level of IL-1ß raised in cortex but not in medulla, whilst the level of IL-6 did not change in renal cortex and medulla. Similarly, they recorded distinguished rise of MDA, due to increase level of prostaglandin-endoperoxide synthase 1 (PTGS1) mRNA that involved in MDA synthesis and the decline in mRNA of MDA catabolic enzyme ALDH1L1. Addition rise in GSH level, while the enzymes SOD and CAT were at lower level in dehydrated camels and no significant changes in their levels in rehydrated and control groups. According to their results, renal medulla presents more tolerance (refractory) toward oxidative stress that result from dehydration than cortex. In addition, long period of dehydration may cause DNA damage, this led to increase p 53- upregulated modulator and apoptosis (PUMA, which is a protein that is activated by p53 in response to cellular stresses,), promoting apoptosis by inducing the expression of pro-apoptotic proteins. This protein will activate pro- apoptosis factors Bcl-2-associated X protein (BAX) and Bcl-2 antagonist killer 1(BAK), which affect on mitochondrial membrane to release cytochrome C (apoptotic inducting factor, AIF), as mentioned by Olivier et al. (2009). Accompanying with p53 elevation, a decrease in B-cell lymphoma-extra large BCL-xL (anti-apoptotic factor, regulate ATP synthesis) in renal medulla and cortex, which also lead to intrinsic pathway (mitochondrial) of apoptosis (Michels et al., 2013).

2- Blood hematology and blood biochemistry

2-1-Blood hematology

2-1-1- Red blood cells

The red blood cells (RBCs) play an important role in camel adaptability to desert conditions rather than white blood cells (WBCs). Because, WBCs, do not show any role in adaptation, but their role is limited to defense against infections (Faye and Bengoumi, 2018).

Camel’s erythrocytes have no intracellular organelles except few numbers of mitochondria. Additionally, there are marginal bans consist microtubules, which associated with red blood cells capacity and its resistance to changes in blood plasma osmotic pressure that occurred due to rehydration. As mentioned previously, after camels have been exposed to a prolonged dehydration, they be able to drink large quantities of water in few minutes, which may harm camels RBCs membrane (Yagil, 1985). Through decreased volume of RBCs due to increased level of blood tonicity, resulting from sodium concentration elevation, this leads to narrowing RBCs. This narrowing caused a decline in mean corpuscular volume (MCH) level and the same for MCH (quantifies the amount of hemoglobin per red blood cell) and mean corpuscular hemoglobin concentration (MCHC) (indicates the amount of hemoglobin per unit volume, correlates the hemoglobin content with the volume of the cell) during dehydration period (Yagil,1985). Moreover, Yagil (1985) stated that during dehydration, water absorption from gastrointestinal tract increases in response to elevated levels of ADH and aldosterone, that may cause RBCs dilution following by decline in their volume.

Yagil et al. (1976) and Yagil (1985) stated that, life span of camel RBCs is ranged from 90 to150 day, depending on environmental conditions. In cold weather, its life span is 90, and 120 in hot conditions, while it reaches to 150 days in case of chronic dehydration. The miracle in increasing life span of RBCs is to serve both water and energy, because blood erythrocytes turnover required water and energy.

The indicator for RBCs suspension in plasma is erythrocytes sedimentation rate (ESR). ESR is a test that indirectly measures the degree of inflammation present in the body (Yagil,1985). The test actually measures the rate of fall (sedimentation) of erythrocytes (red blood cells) in a sample of blood. There are many factors affecting its level of change such as; blood protein, fibrinogen concentration (the main blood protein for ESR). When a sample of blood is placed in a tube, the red blood cells normally settle out relatively slowly, leaving little clear plasma. The red cells settle at a faster rate in the presence of an increased level of proteins, particularly proteins called acute phase reactants. The level of acute phase reactants such as C-reactive protein (CRP) and fibrinogen increases in the blood in response to inflammation. While, albumin and globulin have secondary role for ESR (Faye and Bengoumi, 2018). Moreover, season consider as a vital factor affecting level of ESR change, based on data of Babeker et al. (2011), ESR rate is higher during summer than winter season.

2-1-2- Packed cell volume

Packed cell volume (PCV, %) reflects RBCs number and size, and during dehydration, it is changed due partly to the ability of the red blood cells to shrink. So, the PCV % is considered a good indicator for camel dehydration status (Faye and Bengoumi, 2018). It is also affected by season, Butt and Afzal (1992) recorded higher percent in dromedary camel PCV during summer. This elevation is an indicator for good tissue oxygenation, and would be essentially linked to that of the mean corpuscular volume (Butt and Afzal 1992). During dehydration time, Yagil et al. (1976) and Mohamed et al. (1984) mentioned that, PCV percentage decreased about 3-8.8%.

2-2-Energertic parameters

During dehydration and fasting, camels have remarkable abilities to control their metabolism during this critical period, due to their superior physiological, biochemical and behavioral features. They provide their energy needs via increasing level of energetic parameters and lipid mobilization, stored in hump and from abdominal fat (Faye and Bengoumi, 2018). The basic of camel’s energy requirements are lower than other ruminant species, according to data of National Research Center (NRC, 2001).

Volatile fatty acids (VFAs) are the main source of energy, they are synthesized from carbohydrates (glucose) degradation, dry matter and crude fiber (camel are more efficient in crude fiber digestion than ruminants). They are consisting of acetic acid (77%), propionic acid (16%), and butyric acid (7%) as mentioned by Mohamed and Hussein(1999).

Glucose in camels is normally ranged between 60-140 mg/dl, which is higher than in ruminants (45-80 mg/dl) and in close to mono-gastric animals (70-126 mg/dl) according to Faye and Bengoumi (2018). Camel glycaemia increases with energy intake and during dehydration and stress. Nazifi et al. (1999) recorded higher plasma glucose level in camels in the summer than winter season. Similarly, Bengoumi (1992) and Bengoumi et al. (1998) found that, during dehydration blood glucose elevates, and they attributed this result to decreased plasma volume (deceased about 40% during dehydration) and the declined level of insulin hormone during this period, thus blood glucose elevated.

As for blood lipids, cholesterol in camels is lower (18-150 mg/dl) than other ruminants (Faye and Bengoumi, 2018). It is affected by seasonal variations and feeding status. Bengoumi (1992) reported that, after dehydration days (14 days), plasma cholesterol tends to increase about 25% then returns to its normal level. The same for triglycerides (TG), the indicator of lipid mobilization when animals go underfeeding and do not get their energy needs. Therefore, during dehydration, TG concentration increases which points to lipolysis process to provide camel with energy requirements (Faye and Bengoumi, 2018). Then, their level go back to normal values after rehydration by one week (Faye and Bengoumi, 2018). The non-esterified fatty acids (NEFAs) also known as free fatty acids (FAAs) because they are not esterified with glycerol to form triglycerides, the NEFAs have the same trend of glucose and other mentioned lipids during dehydration. The NEFAs rise during dehydration but with lower level (3.5 nmol/l) than cattle (8 nmol/l) (Faye and Bengoumi, 2018). These elevations in energetic parameters during water deprivation and underfeeding considered as control factors to prevent ketone bodies increase (Faye and Bengoumi, 2018). Concerning phospholipids, the most important component that give unique feature of camel RBCs cell membrane. They also increases during dehydration as the other energetic parameters did (Faye and Bengoumi, 2018).

2-3- Kidney functions

Blood urea nitrogen (BUN), the product resulting from protein digestion, is produced by liver and excreted by kidney. It is normally ranged between 8-30 mg/dl, and when camels exposed to water restriction, a noticeable increase in the level of urea is recorded (reaches to 122 mg/dl). Then back to its normal level after one week of rehydration (Faye and Bengoumi, 2018). The indicator of renal filtration rate is creatinine, that is synthesized in muscles and its normal range is 0.8- 2 mg/dl (Bengoumi, 1992). In case of severe dehydration, kidney filtration rate declines about 72%, causing rises in blood creatinine by 60%, and then significant decline observed after one week of rehydration (Bengoumi, 1992).

2-4- Liver enzymes

In general, when enzymes activity increases, it points to liver cell damage. They passing specific cells to interstitial tissue then to blood. The main indicator for liver cell damage is increasing their levels in urine (Faye and Bengoumi, 2018). Dehydration for more than 25% seems to affect activity of aspartate amino transferase (AST), alanine amino transferase (ALT) and alkaline phosphatase (ALP), according to Mohamed et al. (1984).

2-5- Blood total proteins

In normal conditions, their normal value is 6.3 – 8.3 g/l. However, during water restriction, blood protein increases by 15-25% after 6-8 days of water restriction (Bengoumi, 1992). While in other study, a slight decline in blood proteins concentration was recoded (Mohamed et al., 1984). The authors attributed this decline to, high molecular weight of blood protein that cannot allow them to pass through vascular endothelium.

3- Thermoregulation in camels

In most mammals, fat is spread over the body surface just under the skin. In the camel, the fat is concentrated in the hump which enables sweat to be evaporated easily over the rest of the body surface and this is adaptation to heat transmission (Tibary and El Allali, 2020). The skin is supple, covered with short fine hairs, which act as insulating medium and may be longer in cooler climates or during the cool seasons in hot areas (thermoregulation, Tibary and El Allali, 2020). The poll glands which are situated towards the top of the back of the neck behind ears and cover an area of about 6x4 cm in both sexes (Bornstein, 1990). They are more active during heat stress conditions to help the sweat glands in evaporation, but the poll glands are not active, as they are in during heat stress, when camel male is in rut. In addition, Tibary and El Allali (2020) stated that, during severe heat stress, and when body temperature rises and reaches to 40.5°C, camels are sweat in narrow limits and activate sweat glands to use them in evaporation. Moreover, the rectal temperature in dromedary camels is fluctuated between 6-8°, which enables camel with 600 kg body weight to save about 6 L. In the middle of the day, camel rectal temperature may reach to 43°C, in spite of that camels can live without causing any damage in the functions of the internal organs in the body (Tibary and El Allali, 2020).

One of the most important adaptive mechanisms in camels is bi-phasic breath. Camel nose mucosa have incredible properties, during breath- in phase, mucosa is moist and hydrophobic. This moisture evaporates and cools down the mucosa surface, while, during breathing – out; the mucosa is very dry and hydroscopic. The air is drained and no water get lost (Mulu and Assen, 2018). Under severe thermal stress; camel can protect their brain from damage through brain cooling via rete mirable (Photo, 3). It is a complex network of arteries and venous laying close to each other that give H-shaped (Photo, 4) appearance (Fesseha and Desta, 2020).

As shown in Photo (5), brain cooling is achieved through vasodilatation for venous 1 and 2, and vasoconstriction for facial vein (vein number 3). When this situation occurs the cool venous blood can only go in one direction through the ophthalmic veins to the cavernous sinus which then cools the arterial blood through heat exchange in the carotid artery (Ouajd and Kamel, 2009).

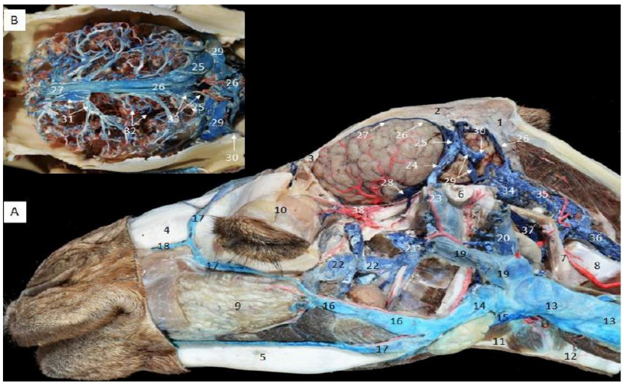

Photo (3). Venous network in the camel's head (Jebri et al., 2018).

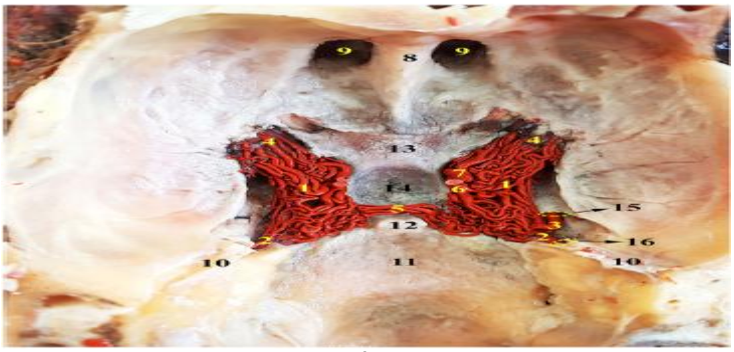

Photo (4). The H shape of camel rete mirable (Al Aiyan et al., 2019).

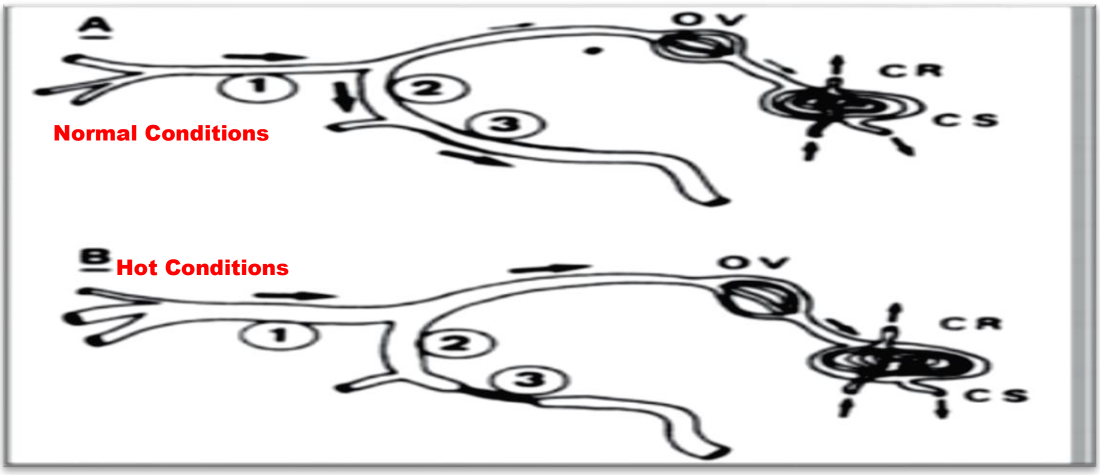

Photo (5). Brain cooling in camels (Mulu and Assen, 2018).

4- Heat shock proteins in camel

Cellular thermo-tolerance is maintained as long as the cell is still having the ability to produce kind of proteins that defense against non- lethal heat stress, called heat shock proteins (HSPs, Al Jassim and Sejan, 2015). However, with continuing the wave of extreme heat stress, the cell will not able to express these proteins and the apoptotic mechanisms will develop causing cell death (Sonna et al, 2002). Camels can possess the expression of heat shock proteins (HSPs), especially HSP70 with molecular weight of 70K Da, known as control factor that possess camel adaptive ability (Al Jassim and Sejan, 2015). The genomic cluster of HSP70 is containing three genes, two of them having heat shock elements that are important in heat shock induction (Garbuz et al., 2011). In addition, HSP73 is well expressed in lymphocytes than RBCs (Ulmasov et al., 1993). Another family of HSPs known as small heat shock proteins (sHSP) are characterized by low molecular weight of 12-13 k Da and play an important role in cell resistance to heat stress (Bakthisaren et al., 2015). Only two members of this family are recognized in camel, which are HSPß5 and HSPß1 (HSP27). The family of HSP90 (with molecular weight of 90 K Da) promote important physiological mechanisms such as cell proliferation, cell differentiation and protein folding (Hoter et al., 2018). The identified members of HSP90 in dromedary camels are HSP90α and glucose regulator protein (GRP 94), localized in endoplasmic reticulaum (ER). The chaperone GRP94 is required to possess the ER functions such as; help in protein folding (Hoter et al., 2018).

5- Camel morphological features

The head of the camel is small in comparison to that of other domestic animals. It bears no horns and has small bluntly erected ears to hear the minimal sound vibration and hear for long distance in the desert. In addition, the ear contains small hairs to filter and warm the air entered the ears in sandy environment. The eyes are large and prominent that enable the camel to see in different directions and for long distances. The massive supraorbital fossa or processes give some protection with the long lashes against the sandy environment of the desert in windy day (Fesseha and Desta, 2020). Also, the nostrils of the camel are long slit-like appearance having wing, so the camel is the only animal who can close its nostril as protection against sand and winds (Fesseha and Desta, 2020). The upper lip is split and hairy, extensible and slightly prehensile, it is very sensitive. This modification helps the camel to select its food (selective feeding) and avoid the thorny plants (Fesseha and Desta, 2020). The camel has a long arched neck helping him to manipulate the high tree plants and to explore the enemy from long distances (Bornstein, 1990). Camels also are characterized by their large body size, which reinforces their adaptability in heat dissipation (Fesseha and Desta, 2020). Additionally, their large size allows them for gaining heat from surrounding environment slower than other animals with small body size (Fesseha and Desta, 2020). The long legs of camels give them the superior anatomical feature, because they keep camel body away from hot sandy and let winds to pass through their legs which achieve to some extent cooling them (Bornstein, 1990). Additionally, camel footpads are large having two fingers nail and their leathering pad protects the legs from lost in desert sand (Fesseha and Desta, 2020).

Conclusions

Camels are the friend of the environment. They have anatomical, physiological and behavioral features that allow them to tolerate and produce under the environmental stressors such as heat stress and dehydration, where the other animals cannot produce or live.

REFERENCES

Abdalla, M. A. 2020. Anatomical features in the kidney involved in water conservation through urine concentration in dromedaries (*Camelus dromedarius*). Heliyon Journal, 6: 31 – 39

Al Aiyan, A., Preeth, M., Adnan, A., Almuhairi, F., Alnuaimi, S., Bulshawareb, A. Moneeb, Q. and Shehab, S. 2018. Descriptive analysis of cerebral arterial vascular architecture in dromedary camel (*Camelus Dromedarius*). Frontiers Neurological Journal, 13: 1-13

Al Jassim, R. and Sejian, V. 2015. Review paper: Climate change and camel production: Impact and contribution. Journal of Camelid Science, 8: 1–17

Ali, A., Abu Damir, H., Amir, H., Adeghate, E. A., Bastaki, S., David, M. and Abdu Adem, A. 2019. Effects of long-term dehydration on oxidative stress, apoptotic markers and neuropeptides in the gastric mucosa of the dromedary camel. Molecular and Cellular Biochemistry, 455:109–118

Ali, A., Abu Damir, H., Osman, M., Amir, H., Saeed, T., Michael, P., Greenwood, P. L., Benjamin, G., David, M. and Abdu Adem, A. 2020. The effect of long-term dehydration and subsequent rehydration on markers of inflammation, oxidative stress and apoptosis in the camel kidney. Veterinary Research, 16: 1-13

Allouch, G. 2016. Anatomical study of the water cells area in the dromedary camels rumen (*Camelus dromedarius*). Nova Journal of Medical and Biological Science, 5: 1-5

Babeker E. A., Elmansoury, Y.H.A. and Suleem, A.E. 2011. The influence of seasons on blood constituents of dromedary camel (*Camelus dromedarius*). Journal of Animal Feed Research, 3:1–8

Bakthisaran, R., Tangirala, R. and Rao, C. M. 2015. Small heat shock proteins: Role in cellular functions and pathology. Biochimica et Biophysica Acta, 1854: 291–319

Bengoumi, M. 1992. Biochimie clinique du dromadaire et mécanismes de son adaptation à la déshydratation, Thèse de doctorat ès Sciences Agronomiques. I.A.V. Hassan II, rabat, Maroc

Bengoumi, M., Essamadi, K., Tressol, J. C. and Faye, B. 1998. Comparative study of copper and zinc metabolism in cattle and camel. Biological Trace Element Research, 2: 81-94

Bornstein, S. 1990. The ship of the desert: The dromedary camel (Camelus dromedarius), a domesticated animal species well adapted to extreme conditions of aridness and heat. Research Management and Husbandry of Reindeer and other Northern Ungulates, 1: 231-236.

Butt, R.S. and Afzal, M. 1992. Seasonal variations in haematological and serum biochemical parameters in racing camels. In: International camel conference, Dubai, UAE, 2–6 Feb 1992. R&W Publications, England

Crawford DT, Suzuki, Davies K (2000) Redox regulation of gene expression, In: Antioxidant and Redox Regulation of Genes, Chandan K. Sen, Helmut Sies and Patrick A. Baeuerle (ed) © 2000 Elsevier Inc, ISBN: 978-0-12-636670-9

Elkhawad, A. O. 1992. Selective brain cooling in desert animals: the camel (Camelus dromedarius). Comp Biochem Physiol 101A:195-201

Faye, B. and Bengoumi, M. 2018. Camel Clinical Biochemistry and Hematology. © Springer International Publishing, ISBN: 978-3-319-95560-5

Fesseha, H. and Desta, W. 2020. Dromedary camel and its adaptation mechanisms to desert environment: A review. International Journal of Zoology Studies, 5: 23-28

Garbuz, D. G., Astakhova, L. N., Zatsepina, O. G., Arkhipova, I. R., Nudler, E. and Evgen'ev, M. B. 2011. Functional organization of hsp70 cluster in camel (Camelus dromedarius) and other mammals. PLoS One, 6 : 1-9

Gaughan, J. B. 2011. Which physiological adaptation allows camels to tolerate high heat load and what more can we learn?. Journal of Camelid Science, 4: 85–88

Hoter, A., Amiri, M., Prince, A., Amer, H., Warda, M. and Naim, H. Y. 2018. Differential glycosylation and modulation of camel and human HSP isoforms in response to thermal and hypoxic stresses. International Journal of Molecular Science, 19: 1-16

Irwin, R. 2010. Camel. Rektion Books Ltd., 1st ed. London, UK

Jebri, H., Aid, K., Vazqous, N. and Perez, W. 2018. Gross anatomy of dural venous sinuses in the one-humped camel (*Camelus dromedarius*, Linnaeus 1758). Journal of New Science and Sustainable Livestock Management, 9: 184-190

Michels, J., Kepp, O., Senovilla, L., Lissa, D., Castedo, M., Kroemer, G. and Galluzzi, L. 2013. Functions of BCL-XL at the Interface between Cell Death and Metabolism. International Journal of Cell Biology, 13: 1-11

Mohamed, H. A. and Hussein, A. N. 1999. Studies on normal haematological and serum biochemical values of the 'Hijin' racing camels (*Camelus dromedarius*) in Kuwait. Veterinary Research Communication, 23:241–248

Mohamed, M. A., Mohamed, A. and Locatelli, A. 1984. Water deprivation effects on the hematological and hematochemical pictures of Camelus dromedarius. Rev. Elev. Med Vet. Pays. Trop., 37:313–317

Mulu, G. G. and Assen, A. M. 2018. Adaptation Mechanisms of Camels (*Camelus dromedarius)* for Desert Environment: A Review. Journal of Veterinary Science and Technology, 8: 1-5

Nazifi, S., Gheisari, R. and Poorabbas, H. 1999. The influence of thermal stress on serum biochemical parameters of dromedary camels and their correlation with thyroid activity. Comparative Haematology International, 9:49–53

NRC. 2001. Nutrient Requirement of Dairy Cattle, 7th Rev. ed. National Academy Press, Washington, USA

Olivier, M., Petitjean, A., Marcel, V., Petre, A., Mounawar, M., Plymoth, A., de Fromentel, C.C. and Hainaut, P. 2009. Review: Recent advances in p53 research: An interdisciplinary perspective. Cancer Gene Therapy, 16:1–12

Ouajd, O. and Kamel, B. 2009. Physiological particularities of Dromedary (*Camelus dromedarius*) and experimental implications. Scandinavian Journal of Laboratory Animal Science, 36: 19-29

Schmidt-Nielsen, K. 1997. Animal Physiology – Adaptation and Environment. 5th, © Cambridge University Press, UK

Sonna, L. A., Fujita, J., Gaffin, S.L. and Lilly, C.M. 2002. Invited Review - Effects of heat and cold stress on mammalian gene expression. Journal of Applied Physiology, 92:1725-1742.

Swenson, M. J. and Reece, W.O. 1993 Dukes' Physiology of Domestic Animals. 11th ed. pp. 9-24. Comstock Publishing Associates, A division of Cornell University Press, Ithaca and London

Tibary, A. and El Allali, K. 2020 Dromedary camel: A model of heat resistant livestock animal. Therionogenology, 15: 203-211

Ulmasov, H. A., Karaev. K. K., Lyashko, V. N. and Evgen'ev M. B. 1993. Heat shock response in camel (*Camelus dromedarius*) blood cells and adaptation to hyperthermia. Comparative Biochemistry and Physiology, 106: 867–872

Willmer, P., Stone, G. and Johnston, I. 2006. Environmental Physiology of Animals. 2nd ed. Blackwell Publishing, ISBN 978-1-405-10724-2

Yagil, R. 1985. The Desert Camel: Comparative Physiological Adaptation. Karger, Basel, 163 p

Yagil, R., Etzion, Z. and Berlyne, G.M. 1976. Effect of dehydration on the urea nitrogen metabolism in the camel. Israel Journal of Medical Science, 12:1514

Zari, T. A. and Al-Hazmi, M. A. 1993. The body temperature and behavior of the Arabian camel, *Camelus dromedarius* in Jeddah, Saudi Arabia. Biology Science, 2: 3-12

الملخص العربي

تغير المناخ والإبل: استكشاف سبل التكيف مع الظروف القاسية

جمال عاشور[1]، خالد البحراوي[2]، سماح محمد عبد الرحمن[3]

[1] قســـم الإنتاج الحيواني، كليــــة الزراعة، جامعة القاهرة، مصر
[2] قسم فسيولوجيا الحيوان والدواجن، مركز بحوث الصحراء، مصر
[3] معهد بحوث الإنتاج الحيواني، مركز البحوث الزراعية، مصر

تتمتع الإبل العربية بخصائص فسيولوجية تجعلها أكثر تحملاً للظروف البيئية القاسية مثل: الإجهاد الحراري، يمكنها تقليل فقدان الماء عن طريق الجهاز الهضمي والبولي. بالإضافة إلى قدرتها على الاحتفاظ بالمياه عن طريق الكرش. علاوة على ذلك، فإن التنظيم الحراري ومؤشرات الدم من بين العوامل التي أعطت الإبل تفوقًا على الحيوانات المجترة الأخرى والتي تساعدها على التأقلم في ظل الظروف الصحراوية وتزيد من قدرتها على إنتاج اللبن واللحم المعروف عنهم بقيمتهم الغذائية العالية.

بالإضافة إلى ذلك، فإن الخصائص المورفولوجية للإبل مثل الرأس الصغير والشعر الصغير في الأذان لتنقية الهواء الداخل الي الأذن في البيئة الرملية. العيون ذات الرموش الطويلة وأخيرًا أرجلها الطويلة، كل هذه العوامل تساعد الإبل على التكيف مع البيئة الصحراوية. لذلك، هذه المقالة تناقش كل هذه الميزات بالتفصيل.

الكلمات الدالة: الإبل، المؤشرات الفسيولوجية، الدم، الكلى، الكرش، الخصائص المورفولوجية