Review paper: Climate change and camel production: impact and contribution

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Abstract

The camel is a multipurpose livestock species of great economic importance due to the benefits provided by camel products (meat, milk, wool). This review provides an overview of the impact of climate change on camel production and its adaptation mechanisms. Emphasis was also given to camel contribution to greenhouse gas (GHG) pool through methane emission. As a species well known for its extreme adaptive capacity for extreme weather conditions as compared to ruminants, camels offer huge scope for protecting the socioeconomic status of poor and marginal farmers by acting as alternate livelihood security in the changing climate scenario. The most contrasting adaptive behaviour of camel over other animals during heat stress condition is to reduce their evaporative cooling mechanisms as a measure of conserving their water resource in the body. Although camel possess extreme thermo-tolerance capability, but still drought has grown as a concern in recent years, leading to shrinkage of grazing land, and the weather extremes can give rise to malnutrition and other health concerns for camel herds. Heat stress seems to have adverse impact on both milk production and milk quality in camel. Heat stress significantly increase the packed cell volume (PCV), haemoglobin (Hb), total protein, albumin, serum glucose, aspartate amino transferase (AST); alanine amino transferase (ALT), tri-iodo-thyronine (T3), and thyroxin (T4) concentration in camels. Further, climate change also increases the incidences of emerging diseases and vector-borne diseases in particular. There are links of climate change on the occurrences of camel pox, peste des petits ruminants, babesiosis, theileriosis and trypanosomosis in camel. The heat shock protein (HSP) 70 was considered to be the ideal biological marker for quantifying heat stress in camel. The camel is a unique animal and its remarkable adaptive characteristic projects it as the animal for future as the world is preparing itself to face the untoward challenges of climate change. Hence considerable research efforts are needed to promote development of this neglected species in the changing climate scenario.

Keywords: Adaptation, camel, climate change, drought, emerging diseases, heat stress, HSP70.

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Introduction

Climate change is real and widely acknowledged by politicians and scientists globally. The changes have occurred at an alarming rate during the past few decades and have started to impact on human and natural ecosystems (Intergovernmental Panel on Climate Change, IPCC, 2014). Changes have been manifested by increase in land and ocean surface temperatures, increases in mean sea level, ocean surface salinity, ocean acidity, and melting of the Greenland and Arctic ice sheets mass. These changes have been attributed mainly to human activities since the pre-industrial era, which were driven by economic and population growth. The IPCC (2014) has shown that the last three decades have been warmer at the earth's surface than any preceding decade since 1850. The globally averaged combined land and ocean surface temperature has risen by 0.85 ^{0}C (0.65 to 1.06) over the period 1880 to 2012 (IPCC, 2014). Although, changes in surface temperature have not been uniformed, with some regions cooling and others warming, but long-term effect and the globally averaged land and ocean surface data is showing a trend toward increased temperature. Key findings of the 2014-IPCC report are:

- Global sea level to rise by 0.19 (0.17 to 0.21) m over the period 1901 to 2010.
- The Greenland and Antarctic ice sheets have been losing mass, especially over the period 2002 to 2011.
- The mean Arctic sea-ice extent decreased over the period 1979 to 2012 in the range 3.5 to 4.1% per decade.
- pH of ocean surface water has decreased by 0.1, corresponding to 26% increase in acidity.

Climate change is an environmental, social and economic challenge on a global scale (Mendelssohn et al., 2006). Despite worldwide coverage of climate change impact, there is inter and intra-sectoral variation in vulnerability depending on location, adaptive capacity and other socioeconomic and environmental factors. In the agriculture sector, climate change has a huge impact and threatens the survivability of poor and marginal farmers by altering their economic status. Within the agriculture sector, livestock are the main subject of discussion as apart from getting affected by climate change they themselves are the contributors to the phenomenon by release of methane (CH_4) and nitrous oxide (N_2O) (Sejian, 2013). The changing climate is expected to have severe impact on livestock production systems across the world. World demand for animal protein will rise as the population and real incomes increase and eating habits change. Therefore, animal production plays and will continue to play a key role in food supply (Sejian et al., 2015a). While the increasing demand for livestock products offers market opportunities and income for small, marginal, and landless farmers, livestock production globally faces increasing pressure because of negative environmental implications particularly because of greenhouse gas (GHG) emission (Sejian et al., 2015b).

Ruminant animals lack the capability to withstand adverse impacts of climate change leading to severe economic crisis with small and marginal farmers around the world. As a result agro-pastoralists around the world and African countries in particular have shifted their production from cattle dominated husbandry to camel and small ruminant production. Camel in particular offers huge scope for protecting the socioecomic status of poor and marginal farmers by acting as alternate livelihood security in the changing climate scenario. However, in recent years due to extreme climatic condition the level of drought are very severe that it affects even the camel productivity, the species well known for its extreme adaptive capacity for extreme weather conditions. Hence, an effort has been made in this review (i) to project the impact of changing climate on camel production, (ii) to assess the adaptive mechanisms of camel face to climatic change, and (iii), to establish the role of camel in contributing to existing greenhouse gas.

1. IMPACT OF CLIMATIC CHANGE

1.1. Impact of climate change on agriculture

Climate changes have both negative and positive impacts on agriculture with the negative impacts being more common. Based on scientific evidence the negative impacts are high and widely spread across continents. Impacts on food production systems, livelihood of agricultural communities, health and/or economics of humans are recorded with high confidence (IPCC, 2014). The negative impact of climate changes on water resources, quantity and quality, is a major destabilizing factor to the already fragile ecosystem and vulnerable agricultural communities. Extended periods of droughts, frequent severe heat waves, extreme floods, cyclones and wildfires are outcomes of such changes. The report has also acknowledged the extreme impacts of climate-related risks on the livelihoods of human particularly those in poverty. The impact is even greater on those who are socially, economically, culturally, politically and institutionally marginalised (IPCC, 2014).

Adaptation of agricultural practices to the new climate is essential if production from land and livestock is to be maintained and agricultural systems are sustained. This is particularly true for crops that are fundamental to food security such as wheat, rice and maize, both in the tropical and temperate regions. It was projected that a change in local temperature by 2 ^{0}C above late 20th century levels will have negative impacts on most of agricultural product (IPCC, 2014). However, when the potential increase in temperature is combined with the projected increase in population and food demand, the risks on food security and human health become greater. Risks are generally greater for disadvantaged people and communities everywhere. However, climate changes are expected to exacerbate poverty and create new poverty pockets in countries with increasing inequality, in both developed and developing countries.

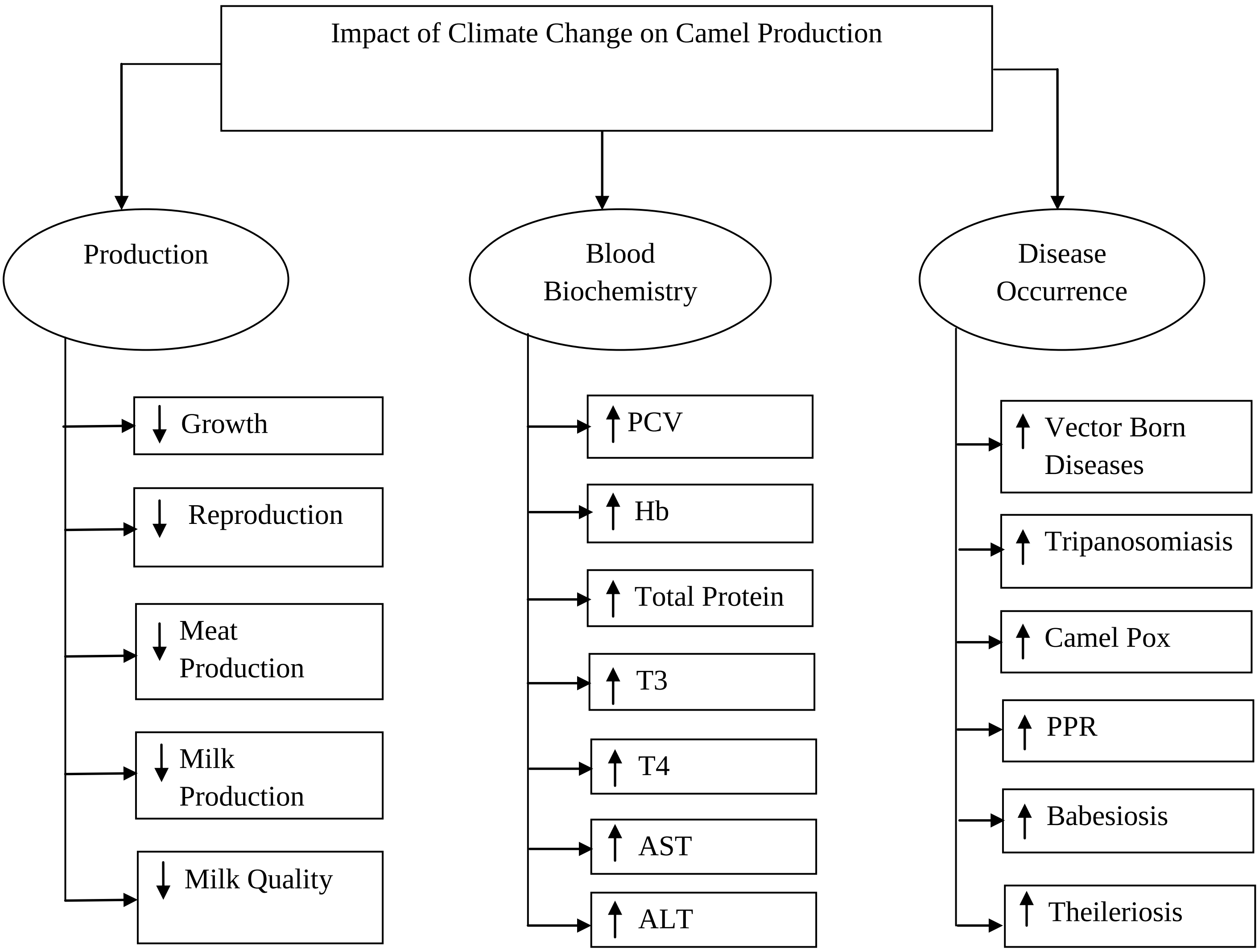
1.2. Climate change and camel production

The camel is a multipurpose livestock species of great economic importance due to the benefits provided by camel products (meat, milk, wool). Camels are essential in arid lands; they are well adapted to hot and arid environments, desertification and scarce natural resources (Faye, 2011). Camel production is a major source of livelihood for the pastoralists in the arid and semi-arid lands (Hulsebusch and Kaufmann, 2002; Faye, 2014). Eighteen million of the 28 million camels in the world are located in the East African countries of Ethiopia, Somalia, Djibouti, Eritrea and Sudan (Faye and Bonnet, 2012). The arid climate of the region limits options for raising livestock, but camels, which can go up to a week without water, have the advantage of being one of the most drought-resilient species.

In recent years, understanding the impact of changing climate on agriculture and in livestock in particular have gained momentum as majority of the developing countries rely heavily on agricultural productivity for the country's economy. Majority of the published report on impact of climate change on livestock production seems to be in large and small ruminants. Despite the advantages the camel has over other domestic animals, it has been neglected, with most research efforts being directed to cattle, sheep and goats, among others. Although camel possess extreme thermo-tolerance capability, but still drought has grown as a concern in recent years, leading to shrinkage of grazing land, and the weather extremes can give rise to malnutrition and other health concerns for camel herds. Also, with the advent of global warming, the risk of camels being epidemiologically involved in the spread or transmission of emerging and re-emerging diseases is also very likely to grow. Exotic diseases associated with camels are also likely to increase, as a result of camels coming into close contact with other livestock species due to the scarcity of water resources.

1.3. Impact of climate change on milk production and composition in camel

Camels are well known for maintaining milk production during drought condition. They produce more milk for longer periods during drought than any other domestic animal adapted to arid habitats, and this is of great importance to pastoralists and agro-pastoralists. However if the drought condition prolonged camels showed reducing trends on milk production during heat stress conditions. Severe water deprivation during heat stress was found to reduce the milk yield in camel and the reduction was generally proportional to the quantum of dehydration. Season strongly affects camel milk composition through heat stress, feed available quality and water availability by affecting the total solids of milk and this directly affects the other components of camel milk (Parraguez et al., 2003). Further, location specific influence on milk composition in camel was reported by Shuiep et al. (2008) and attributed this difference to different management systems and variation in quality and quantity of feed available between the locations. Shuiep et al. (2008) also reported negative impact of summer heat stress on camel milk. They observed significant influence of season on milk composition in camel with high water content in summer samples negatively affecting camel milk components compared to winter samples. Musaad et al. (2013) observed seasonal variation for milk components in Camel. However, they identified that influence of season differed with each components of Camel milk. They established significantly lower milk fat during summer season. Further, they also observed maximum protein content during February and minimum in October. Similarly, lactose content was also observed to be significantly higher in February and minimum during September. Fig.1 describes the impact of climate change on camel production.



PCV-Packed Cell Volume; Hb-Haemoglobin; T3-Tri-iodo-thyronine; T4-Thyroxine; AST-Aspartate Amino Transferase; ALT-Alanine Amino Transferase; PPR- Peste des petits ruminants

Figure 1. Impact of climate change on camel production

2. ADAPTIVE ABILITY OF CAMEL

2.1. Climate change and advantages of rearing camel over other livestock

Camels have been referred to as the desert dairy due to the important roles they play in the arid and semi-arid tropical environments (Field, 2005). Camels possess extreme adaptive capability in terms of coping to harsh environmental condition through their superior biological and physiological adaptive capabilities. They have remarkable tolerance to dehydration even up to a week in contrast to other animals and they can survive on wide varieties of feed resources like shrubs and trees (Kagunyu and Wanjohi, 2014). These qualities of camel have huge benefit in contrast to cattle which needs lot of forages which is difficult to supply during drought conditions and sheep which cannot survive without water for many days. Camels can contribute to food security, given the lower ability of cattle to withstand the harsh climatic conditions associated with climate variability. Kagunyu and Wanjohi (2014) further concluded that camel play a crucial role in hot arid and semi-arid regions to maintain food security, response to climate variability and income generation.

2.2. Potential superior adaptive capability of camels over other animals

Abdoun et al. (2012) reported a better adaptive capability of camel as compared to sheep with similar ambient environmental condition in terms of seasonal variations in body temperature and blood biochemistry. In a similar study on comparison of adaptive capability of camel and goat during summer season, Samara et al. (2012) established the superior adaptive capability of camel over goat. They observed that water deprivation accompanied with heat stress affected the circadian rhythm of core body temperature in both species, but the effect was delayed in camels compared to goats. Water deprivation for 72 hours increased most of the measured haematological and biochemical parameters in both species, but camels exhibited smaller percentage changes compared to goats (Samara et al., 2012). Fig.2 describes the mechanisms by which camel survive effectively in extreme climatic conditions as compared to other animals.

The contrasting adaptive behaviour of camel over other animals during heat stress condition is to reduce their evaporative cooling mechanisms as a measure of conserving their water resource in the body. This is in total contrast to other large animals that rely heavily on their evaporative cooling mechanisms to withstand heat stress. The striking adaptive difference with camel as compared to other animals is that their ability to keep the body temperature well below the normal range during night (Schroter et al., 1987). This allows them to store body heat without switching to respiratory evaporative cooling mechanisms during day time. As evaporation is by far the major component of water loss in a hot environment, a reduction of evaporation will be an effective form of water conservation. In addition, the camel can desiccate the exhaled air so that its relative humidity is less than 100% (Schmidt-Nielsen et al., 1981). Another potential mechanism adopted by camel for reduction of the respiratory water loss is an increased oxygen extraction with attendant reduction in ventilation (Schroter et al., 1987). Water conservation in the camel is enhanced through an ability to produce highly concentrate urine and at the same time dramatically restrict urine output. These two mechanisms, high concentration and low urine flow, combine to significantly reduce water loss more than any other livestock species. This comparatively small water loss in urine together with an ability to produce very dry faeces ensures that only minimal essential body moisture is lost during the elimination of metabolic wastes (Zine Filali et al., 1992). This typical adaptive behaviour helps camel to spend less energy and water in maintaining body temperature within acceptable physiological limits when compared to that of sheep and cattle under similar arid environmental conditions. This allows them to graze over a wider range away from permanent water sources.

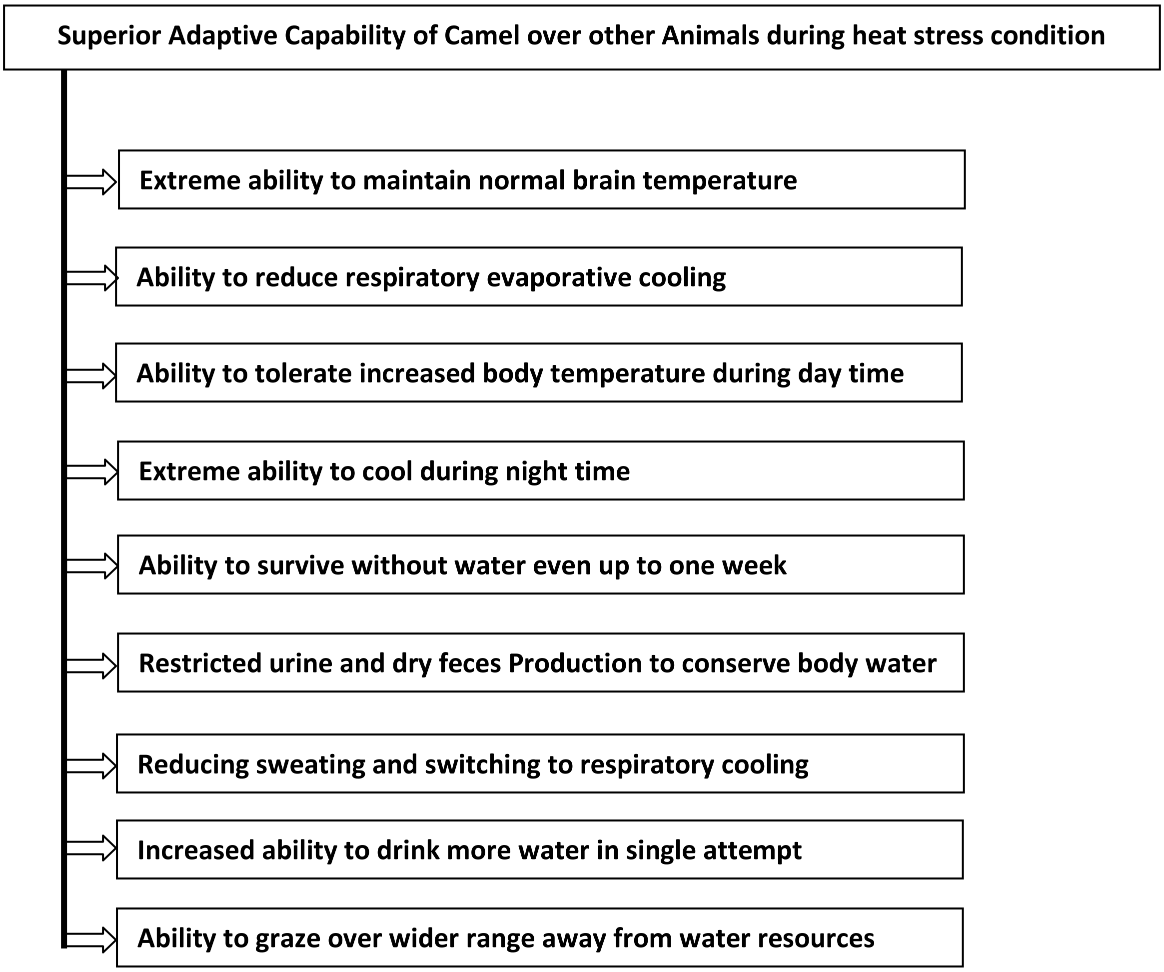


Figure 2. Potential advantage of camel as compared to other domestic animals to survive climate stress

2.3. Heat stress impact on blood biochemical response of camels

Changes in haematological and biochemical parameters during different seasons of the year might have an important role in adjusting the different functions of the animal's body with less physiological efforts within the so called neutral zone to the existing environmental conditions in camels. Heat stress significantly increased packed cell volume (PCV) serum osmolality, serum sodium, total protein and albumin concentration and serum glucose concentration significantly reduced in male Majaheem camels (Samara et al., 2012). Further, breed differences were observed in the level of PCV in camel exposed to summer heat stress (Abdoun et al., 2013). They observed that exposure of camel breeds to heat stress conditions resulted in variable breed-dependent thermo-physiological responses. The observed higher PCV values have been reported to be an adaptive mechanism of desert animals to provide the necessary water required for evaporative cooling process (Al-Haidary, 2004). A similar breed differences on PCV level of camels exposed to heat stress was also reported by Al-Haidary, (2013). Badawy et al. (2008) reported significant influence of season on blood biochemical parameters in camels. They observed significantly lower erythrocyte counts, PCV, haemoglobin concentration and mean cell haemoglobin concentration during summer season in camels, which was in contrast to the discussion on PCV by the earlier researchers in this sub section. They attributed this difference with other studies to *ad libitum* water availability to the camels in their study, which caused hemodilution resulting from increasing water intake during summer season. These authors also observed significantly lower total leukocyte count during summer with reports of significantly higher neutrophil count and lower lymphocytes during summer season in camels. Decreased leukocyte counts in summer compared with winter could be attributed to the reduction in corticosteroids secretion due to prolonged exposure to high environmental temperature during the summer season (El-Banna et al., 1981). Among the biochemical parameters, Badawy et al. (2008) observed significantly higher total protein, albumin, creatinine, urea and total lipids. These results confirm those reported by Nazifi et al. (1999). The elevation of blood urea might be due to the combined pre-renal effects of reduced infusion with lower glomerular filtration and greatest load due to increased metabolic activity (Al Qarawi and Ali, 2003). The significantly lower blood glucose level in Badawy et al. (2008) study was in contrast to Nazifi et al. (1999) who reported significantly higher concentration of serum glucose in summer than in winter. This discrepancy in the season effects on blood glucose in camels may be due to breed differences and to the environmental conditions particularly feeding and watering systems. The increased blood glucose level during summer may be due to decreased basal metabolic rate and reducing the use of glucose for energy production under hot climatic conditions. Etzion et al. (1987) conducted a detailed study in camel and established that when the camels were dehydrated there was serum storage of iodide confirming the decline in thyroid metabolism to cope up to the dehydration condition. Further, they also observed that dehydration was also found to increase the serum bromide concentrations in camel indicating a role for these halide compounds to counter dehydration. Nazifi et al. (999) also reported significant ($p <0.05$) differences in serum calcium, inorganic phosphorus, triiodothyronine (T3) and thyroxine (T4) and the activities of aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), creatine kinase (CK) and lactate dehydrogenase (LD) in heat stress and cold stress conditions in camels. They observed significant correlation between thyroidal hormones (T3 and T4) with serum total protein, glucose, BUN, AST, ALT, ALP, LD and CK. They attributed this strong correlation to increased heat adaptation in dromedary camels. Thyroid hormones (T3 and T4) showed significant positive correlations with serum AST, ALT and ALP activities, corresponding to higher activity of thyroid gland in heat conditions and heat adaptation of the camel. Similarly Tajik et al. (2013) also reported strong correlation of T4 with serum triglycerides and cholesterol in dromedary camels but did not found any correlation with total protein.

2.4. Role of heat shock proteins (HSPs) in camel adaptation

The HSPs are ubiquitous, induced under a number of metabolic and environmental stresses. Like other mammalian species, camels are also known to possess HSP70 family genes to control their adaptive mechanisms (Tariq and Hussain, 2014). *Camelus dromedaries* domesticated under semi-desert environments, is well adapted to bear and survive against severe drought and climatic extremes for extended periods. The HSP70 was identified to be the most crucial factor controlling this extreme adaptive capability of camels (Elrobh et al., 2011). The genomic cluster of *Camelus dromedaries* had been sequenced holding three HSP70 family genes joined with major histocompatibility complex (MHC) class III region from heat tolerant creature (Terada and Mori, 2007). Comparison of the camel HSP70 cluster with the relating areas from several mammalian species are being carried out and further studies in this area may give the confirmatory biological reasons for superior adaptive capacity of camels as compared to other domestic animals (Garbuz et al., 2011).

2.5. Climate change and camel diseases

One of the significant indirect effects of climate change on livestock production is by causing new emerging diseases by creating more favourable conditions for microbes, parasites or vectors to develop. Drought has grown as a concern in recent years as a result of climate change, leading to shrinkage of grazing land, and the weather extremes can give rise to malnutrition and other health concerns for camel herds. The prevailing climate in Middle East, African countries and Australia has a large impact on diseases that target camels. The high health constraints in camel farming in these countries are well known and have been listed for a long time under the main classical diseases such as trypanosomosis, mange, camelpox or gastro-intestinal parasitism (Wernery and Gaaden, 2002). According to Faye et al. (2012) current unbalanced climate seem to contribute to emerging diseases with complex and often unknown aetiologies, caused high unexplained deaths in camels. They opined that the global climate trends would trigger more changes of camel farming systems in Saharan countries if climate change intensifies continuously in the next decades. The past two decades there were reports on sudden outbreak of new emerging diseases like highly contagious respiratory syndrome in Africa (Roger et al., 2000); peste des petits ruminants (PPR) and rinderpest in Sudan and Kenya (Khalafalla et al., 2005); and anaplasmosis, babesiosis and theileriosis in sub Saharan Africa (Olwoch et al., 2007). In areas where the growing period will be too short and no longer will support crop cultivation, pastoralism may become the only sustainable source of food production. In view of this, more efforts to promote the husbandry and veterinary services of the camels including diagnosis, control, prevention and treatment of diseases of these important food security animals are essential to be addressed (Bornstein and Younan, 2013). Also, with the advent of global warming, the risk of camels being epidemiologically involved in the spread or transmission of emerging and re-emerging diseases is also very likely to grow. Exotic diseases associated with camels are also likely to increase, as a result of camels coming into close contact with other livestock species due to the scarcity of water resources.

3. CONTRIBUTION OF CAMEL TO CLIMATIC CHANGE

3.1. Contribution of livestock to GHG emission

Livestock contribute to GHG emission either directly from enteric fermentation and manure management or indirectly from feed production activities and conversion of forests to pasture (Hristov et al., 2013). Various sources provided different estimates for such contribution with values ranging between 7 and 18%. Steinfeld et al. (2006) estimated that the livestock sector emits about 7.1 Gt of CO2-eq, or about 18% of total global anthropogenic GHG emissions. The US Environmental Protection Agency (EPA, 2006) predicted global enteric CH_4 emission to be 2079 and 2344 Mt CO_2-eq per year for 2010 and 2020 respectively, and CH_4 emission from manure storage were estimated to be 470 and 523 Mt CO_2-eq per year, respectively. According to EPA (2011), livestock accounted for about 3.1% of the total GHG emission in the US in 2009, but was the second largest emitter of CH_4 (28% of total emission) and animal manure was the third largest source of N_2O (6% of the total emission).

Enteric CH_4 emission is often expressed as % of gross energy intake (%GEI), with values ranging between 6 and 10% (McDonald et al. 2011). Hristov et al. (2013) suggested expression of GHG emission on a digestible energy intake (DEI) basis or per unit of animal product rather than GEI. Expression of GHG emission as %DEI reflects the potential impact of diet quality and composition. For example, increasing forage digestibility will reduce will generally reduce GHG emission from rumen fermentation per unit of animal product (Hristov et al., 2013). Subject to cost and potential associative effect on digestion of fibre constituents of the basal diet and intake, inclusion of oil or concentrate offer potential mitigation strategies. Natural compounds like tannins and saponins may also reduce enteric CH_4 emission. Nitrate also offers additional benefits to being a cheap source of non-protein nitrogen source (NPN) in lowering enteric CH_4 emission (Nolan et al., 2010; Hulshof et al., 2012).

In addition to enteric GHG emission, emission from faeces and urine is also influenced by diet composition, and depends on whether animal are housed indoor or on pasture (Hristov et al., 2013). Increased digestibility of dietary constituents is expected to decrease fermentable organic matter in faeces, which may decrease manure CH_4 emission. Special attention must to be given to protein supply, quantity and quality, in order to improve utilization of protein, increase retention and decrease excretion in urine and faeces. A balanced diet will ensure efficient utilization of nutrients and improved animal productivity, which will results in lower GHG emission per unit of livestock product. This is an effective mitigation strategy that is highly recommended. Reducing the time allowed for microbial fermentation during the storage can also decrease GHG emission from manure.

3.2. Methane emission from camels

In the 2006 IPCC report, the key reference for CH_4 emission from enteric fermentation in livestock, camels were considered as ruminant animals and therefore were grouped with cattle, buffalo, sheep and goats. However, due to a lack of information on camels' nutrition and digestion processes, the IPCC Tier 1 method was used and approximate enteric emissions were derived by extrapolation from main livestock categories that are considered to have a similar digestive system (Al Jassim and Hogan, 2012). In this report the estimate of enteric methane emission was 46 kg of CH_4/head/year for a camel weighing approximately 570 kg. This weight corresponds to a metabolic body weight ($kg^{0.75}$) of 116.7 kg making the estimated emission value of methane to be 0.3942 kg $CH_4/kg^{0.75}$/year or 1.08 $mg/kg^{0.75}$/day. This figure was derived from an earlier report by Gibbs and Johnson (1993), who extrapolated methane emission figures for camels from cattle measurements.

The report was detailed, based on extensive search of the literature and utilised available resources but ignored the fundamental differences between camels and the true ruminant species of animals which led to the use of a default value of 46 kg CH_4/head/year for camels. Although the report acknowledges indirectly the lack of information on camels, it has accepted a methane emission figure for camels that was extrapolated from cattle experiments without any adjustment to allow for differences in intake, feeding behaviour, fermentation processes and production between camels and cattle (Al Jassim and Hogan 2012).

Calorimetric estimates of methane emission from camels fed different levels of a diet consisting of barley grain and what straw and during fasting were reported by Guerouli and Wardeh (1998). Methane emission was estimated to be 0.999, 0.285, and 0.642 mg/kg$^{0.75}$/day, during the periods fasting, feeding and re-feeding, respectively. These values correspond to a total 26.3, 32.6 and 38.6 kg CH_4/year for 300, 400 and 500 kg live weight camels during the feeding period; 7.5, 9.3 and 11.0 kg CH_4/year during fasting and 16.9, 21.0 and 27.3 kg CH_4/year during re-feeding periods. This calorimetric measurement of methane represents total methane emission from the camel. It is important to mention here that concentrate supplementary feeding is common in camels but does not reflect the normal feeding situation for this herbivore animal. Recent estimates of CH_4 emission from camels (*Camelus dromedarius*) were compared to that from Holstein dairy cattle under the same diets and housing conditions (Guerouali and Laabouri, 2013). Camels and cattle were housed individually, fed lucerne hay (2 kg/day) and barley grain (3 kg/day) and CH_4 emission was measured using face mask open circuit system. Methane emission from camels was 1/3 that from cattle (47.7 vs 138.7 g/day or 17.4 vs 50.6 kg/year). These estimates are similar to those earlier reported by Guerouali and Wardeh (1998) using calorimetric chamber. On the other hand measurements of methane emission by alpaca (*Lama pacos*) and sheep by Pinares-Patino et al. (2003) using the sulphur hexafluoride tracer techniques showed no differences in CH_4 emission (% gross energy intake) between the two species when fed alfalfa hay indoor (5.7 *vs* 4.7). However, alpaca had a higher CH_4 emission when fed the improved perennial ryegrass/white clover pasture (9.4 *vs* 7.5) and Lotus (6.4 *vs* 2.7). It was suggested that differences between alpaca and sheep in particulate fractional outflow rate might have been the underlying physiological mechanism responsible for the differences in CH_4 emission. More recently, measurements of methane emission using respiration chamber with three camelid species (*Vicugna pacos*, *Lama glama*, *Camelus bactrianus*) showed that camelids produced less methane than ruminants (0.229 vs 0.415 g kg^{-1} d^{-1}) on similar roughage diets (Dittmann et al. 2014). The three camelids were chosen to cover a range of body mass (50-760 kg) corresponding that of the domestic ruminants. These researchers concluded that this difference is most likely due to the generally reduced metabolism, food and (digestible) fibre intake of camelids.

Information on methane emission by camelids in general and camels in particular is limited and more work is required especially under normal feeding conditions. In addition, little is known about the diversity and structure of the archaeal population in the gastrointestinal tract of the camelids. A study into the population structure of faecal methanogenes in Bactrian camels (*Camelus bactrianus*) maintained in captivity from two zoos in the USA was carried out using separate 16S rRNA gene libraries for each zoo (Turnbull et al., 2011). While methanogen sequences belonging to the genus *Methanobrevibacter* were dominant in both libraries, they showed significant differences in diversity and structure. It was concluded that these preliminary results highlight how methanogen population structures can vary greatly between animals of the same species maintained in captivity at different locations. Authors also suggested the need to carry out additional studies using alternative techniques such as next generation sequencing to analyse a larger group of animals under controlled diets will be required in order to gain further insight into the diversity of gastrointestinal methanogens in captive and wild Bactrian and Dromedary camels (Turnbull et al., 2011).

Concluding remarks

Livestock contribute to GHG emission either directly from enteric fermentation and manure management or indirectly from feed production activities. Sufficient research efforts are needed to adapt the livestock production system to changing climate apart from targeting reduction of methane production from these species to reap the benefits in the long run.

Our knowledge of camel biology is inadequate. Areas of ignorance are currently being filled by extrapolation from data obtained with cattle but the validity of such extrapolation has, in general, not been adequately tested. Certainly, well known physiological differences between the two species, in areas such as water metabolism and the functioning of a four- compartment stomach in cattle compared with a three compartment stomach in the camel have been investigated but data on the consequences of these differences to nutrient supply and utilization are lacking. In another direction, the rumen microbial eco-system in cattle has developed around daily feed and water consumption. What is the effect on the corresponding ecosystem in camels of intermittent water intake and what in turn does an altered microbial population have on fermentation of feed, feed intake and nutrient yield? The camel has adaptive advantages over ruminant species that make it ideally suited for the production of meat and milk in semi-arid regions. The area of such regions, currently large and increasing in size, is likely to expand further under the influence of global warming. It has been postulated that a time will come when such regions will no longer be suitable for sheep and cattle and their logical replacement would be the camel.

Camel is a unique animal and their remarkable adaptive characteristic projects it as the animal for future as the world is preparing itself to face the untoward challenges of climate change. Efforts are needed to identify the hidden intricacies of the extraordinary adaptive nature of this multipurpose species on the earth whose fortunes are still not fully exploited. Camel might be an exceptional animal for food security during climate change due to its well adaptive capability and its ability to thrive well on any type of pastures. Sufficient research efforts are therefore needed to promote development of this neglected species and such efforts may prove very vital from food security point of view in the changing climate scenario.

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