Chapter 1
Introduction

Veerasamy Sejian

Abstract Animals live in complex environments in which they are constantly confronted with short- and long-term changes due to a wide range of factors, such as environmental temperature, photoperiod, geographical location, nutrition, and socio-sexual signals. Homeostasis, the state of relative physiological stability in an organism, is a prerequisite to survive. Despite changes in environmental conditions, many living species have the ability to maintain their homeostasis within fixed limits by means of a set of specific innate repertoire of counter regulatory behavioral and physiological mechanisms. When the individual innate and acquired repertoire of counter regulatory mechanisms are overridden by environmental or internal perturbations a state of stress is reached and the 'stress responsive systems' are activated. The 'stress system' consists of neuroanatomical and functional structures that produce the behavioral, physiological, and biochemical changes directed toward maintaining homeostasis, when threatened. The environment surrounding livestock plays a significant role in influencing their productivity. Among the environmental variables affecting livestock, heat stress seems to be one of the most intriguing factors making difficult animal production in many of the world areas. Though the animals live in a complex world but researchers most often study the influence of only one stress at a time since comprehensive, balanced multifactorial experiments are technically difficult to manage, analyze, and interpret. There is, in general, a strong relationship between agro-climatic conditions, population density, cropping systems, and livestock production. Rangelands are the largest land use systems on the Earth. They predominate in semi-arid tropical areas of the world. These pastoral systems are those in which people depend entirely on livestock for their livelihoods. The key constraints of arid and semi-arid tropical environment are their low biomass

V. Sejian (✉)
Division of Physiology and Biochemistry, Central Sheep and Wool Research Institute, Avikanagar, Jaipur, Rajasthan 304501, India
e-mail: drsejian@gmail.com

V. Sejian et al. (eds.), *Environmental Stress and Amelioration in Livestock Production*, DOI: 10.1007/978-3-642-29205-7_1,

productivity, high climatic variability, and limited availability of water. All these constraints make these regions difficult for sustainable livestock production. Research agendas need to take into account the trade-offs and synergies arising from these livestock population in tropical environments so that the poor are able to reap the multiple benefits provided by these ecosystems.

Keywords Adaptation · Climate change · Environmental stress · GHGs · Grazing Ruminants · Livestock Economy · Mitigation · Multiple stress · Production · Reproduction · Stress mitigation

Contents

Livestock have been an integral part of the human civilization from times immemorial (FAO 2006). Humans have lived and learned to control domesticated animals for more than 10,000 years (Dib 2010). Over these years, human behavior changed and wild animals with potential to be explored became tamed. Livestock provide a diverse number of products that promote quality of human life, such as wool, skin, meat, milk, eggs, among others. They have also been used for transportation, labor and traction, companionship, hunting along with other activities for necessity or recreation of human.

As time progressed, mankind invented and discovered new technologies and ways to live life comfortably and leisurely. Increase in population created several challenges, such as food, shelter, clothing, etc. which in turn presented the need of synthetic food production, increased demand for land area, and excessive textile manufacturing and hence the need for industrialization. In the course of fulfilling his ever-increasing demands, mankind caused drastic changes in land use through deforestation and cultivation. Along with combustion of fossil fuels, emissions of greenhouse gases (GHGs) have and will alter the climatic patterns. The industrialization, technological advent, and population explosion together brought about drastic changes in the environment such that it has reached alarming levels. The adverse consequences of industrialization, e.g., pollution, air; water; soil and noise, deforestation, etc. are leading to a gradual increase in atmospheric temperature, increase in extreme events, such as droughts, increased incidences of natural calamities, melting of glaciers, rise in sea-level, ozone layer depletion, among others. Ecosystems including plants, animals, and birds cannot adjust and adapt to rapid changes in temperature, precipitation, and other extreme climatic events.

Animals live in complex environment in which they are constantly confronted with short- and long-term changes due to a wide range of factors, such as environmental temperature, photoperiod, geographical location, nutrition, and socio-sexual signals (Kleemann and Walker 2005; Ali and Hayder 2008). Homeostasis, the state of relative physiological stability in an organism, is a prerequisite to survive. Despite changes in environmental conditions, many living species have the ability to maintain their homeostasis within fixed limits by means of a set of specific innate repertoire of counter regulatory behavioral and physiological mechanisms. When the individual innate and acquired repertoire of counter regulatory mechanisms are overridden by environmental or internal perturbations a state of stress is reached and the 'stress responsive systems' are activated (Johnson et al. 1992; Karman 2003). The 'stress system' consists of neuroanatomical and functional structures that produce the behavioral, physiological, and biochemical changes directed toward maintaining homeostasis when it is threatened (Karman 2003).

There is, in general, a strong relationship between agro-climatic conditions, population density, cropping systems, and livestock production (Marai et al. 2007; Ali and Hayder 2008). Rangelands are the largest land use system on the Earth. They predominate in semi-arid tropical areas of the world. In some of these pastoral systems, people depend entirely on livestock for their livelihoods. The key constraints of arid and semi-arid tropical environment are their low biomass productivity, high climatic variability, and limited availability of water (Sejian et al. 2010a; Maurya et al. 2010). All these constraints exacerbate the challenges of sustainable livestock production in the rangeland ecosystems. Thus, research agendas must take into account the trade-offs and synergies arising from these tropical environments so that the resource poor land managers and farmers can harvest the multiple benefits provided by these ecosystems.

Seasonal variations in climatic conditions impact the availability of feed in the livestock. Over and above the effect of seasonal variations that cause considerable economic hardship, it is the unforeseen and unexpected periods of inclement and severe weather conditions which exacerbate the gross economic losses. In addition to mortalities of livestock associated with severe climatic conditions, reductions in reproductive and productive performances generate sizeable economic setback. Impressive advances in research have been made to assess the impact of climatic stressors on the physiological and dynamic responses of livestock. At the same time livestock managers and farmers continue to search for management options which can alleviate and reduce the effects of severe weather on livestock performance and productivity.

1.1 Economic Importance of Livestock

Livestock sector includes animal husbandry, dairy, and fishery. It plays a significant role in national and international economy, and in socio-economic development. In developing countries and emerging economies alike, it has a critical role in contributing to the rural economy by supplementing family incomes and generating gainful employment, particularly among the landless laborers, small and marginal farmers, and women (FAO 2009). Environmental factors affecting livestock productivity are discussed below.

1.1.1 Heat Stress in Livestock

Environmental stresses reduce the productivity and health of livestock resulting in significant economic losses. Livestock productivity is thought to be affected by many factors including, biomass productivity, photoperiod, geographical location, age, breed, nutrient availability, water availability, management practices, environmental conditions so on, and so forth (Khalifa 2003). Of all these factors, environmental condition influencing livestock productivity is of major concern (Shelton 2000; Koubková et al. 2002). Among the environmental variables, heat stress seems to be the most detrimental factor affecting livestock production (Rivington et al. 2009). Heat stress can cause a significant financial burden to livestock producers by decreasing milk and meat production, decreasing reproductive efficiency, and adversely affecting livestock health. Heat stress is a significant issue for livestock grazing in the tropics and subtropics and the effects of heat stress may aggravate with prospects of global warming caused by the accelerating emission of GHGs. Heat stress affects animal performance and productivity at all stages of the life cycle. The adverse effect of heat stress in livestock may be attributed to repartitioning of energy necessary for maintenance of homeothermy. The impact encompasses decreased growth, reduced milk yield, decreased reproduction, increased susceptibility to diseases, and delayed initiation of lactation. Heat stress in cattle reduces feed intake and growth, and in extreme cases can cause death, resulting in substantial revenue loss to producers (Brown-brandl et al. 2005). Heat stress also negatively affects reproductive function (Maurya et al. 2004; Sejian et al. 2011b). Infact reproductive inefficiency is one of the most costly production-limiting problems facing the livestock industry. Heat stress causes infertility in farm animals and this represents a major source of economic loss to the farmers. Reproductive processes in both the male and female are sensitive to environment. As a general rule, increased temperature decreases ovulation rates, shortens duration of estrus, decreases fertility of males, and increases rate of embryonic mortality. Given the associated economic losses through heat stress in several livestock species, additional research is needed on the interactions among heat stress, nutritional requirements, immunological status, and the overall livestock performance.

1.1.2 Economic Losses by Heat Stress

The livestock sector is socially, culturally, and politically significant both nationally and globally. It accounts for 40% of the world's agricultural gross domestic product (GDP). It employs 1.3 billion people, and creates livelihoods for one billion of the world's population living in poverty (Gaughan et al. 2010). Global demand for livestock products is expected to double during the first half of this century (FAO 2009), as a result of the growing human population, and its growing affluence. Hence it is of utmost importance to concentrate on improving the productivity of livestock to meet the growing needs of human population.

Although most livestock possess well-developed mechanisms of thermoregulation, they may not be able to adequately maintain homeothermy under heat stress, especially the high producing animals (Gaughan et al. 2010). Indeed, the hyperthermia negatively affects any form of productivity, regardless of breed, and stage of adaptation (Marai et al. 1999). An understanding of the control of body temperature in livestock under heat loads, and the relationship of this to productivity must come from an approach in which the animal is viewed in relation to both its thermal and nutritive environments (Sejian et al. 2010a). Exposure to elevated ambient temperature evokes a series of drastic changes in the livestock biological functions that include depression in feed intake efficiency and utilization; disturbances in metabolism of water and protein; and alteration in energy, and mineral balances, enzymatic reactions, hormonal secretions, and blood metabolites. Such physiological changes lead to a low live body weight and impaired reproduction, i.e., depression in age at puberty, reproductive activity, and fertility (Marai et al. 2009). As a result the production potential of the livestock species are directly under threat leading to severe economic losses.

1.2 Stress and Reproduction

Reproductive axis is one plane where stress effects are most pronounced and have gross economic impact. Stress activates systems which influence reproduction at hypothalamus, pituitary, or gonads levels. The reproductive axis is inhibited at all levels; steroidogenesis is directly inhibited at both ovaries and testes. The principle target is the GnRH neuron activity thus affecting the GnRH secretion into the hypophyseal portal blood. Stress can also affect the gonadotrophic cell responsiveness to GnRH. Glucocorticoids are critical to mediate inhibitory effect on reproduction. Environmental stresses affect the estrous behavior, embryo production, birth weights of lambs, placental size, and function and foetal growth rate.

Several factors affect the reproductive performance of farm animals, among which the physical environment and nutrition play a significant role (Gaughan et al. 2009). Proper nutrition supports mediocre biological types to reach their genetic potential, and may even alleviate the negative effects of a harsh physical environment. Poor nutrition on the other hand, may not only exacerbate detrimental environmental effects, but also reduce performance to below the genetic potential. In other words, nutritional factors appear quite important in terms of their direct effects on reproduction, and the potential to moderate the effects of other factors. Most reproductive responses to environmental factors are coordinated at the brain level, where all external and internal inputs ultimately converge into a final common pathway that controls the secretion of gonadotrophin-releasing hormone (GnRH). In turn, this neurohormone controls the secretion of gonadotrophins, the pituitary hormones that determine the activity of the reproductive axis (Martin et al. 2004). Reproductive fitness may be regarded as the most important criteria for studying or evaluating of animal adaptation. Body systems activated by stress influence reproduction by altering the activities of the hypothalamus, pituitary gland, or gonads. Reproduction processes in animals may be impacted during heat exposure, and glucocorticoids are paramount in mediating the inhibitory effects of stress on reproduction (Kornmatitsuk et al. 2008).

1.3 Significance of Optimum Nutrition to Livestock Production

Livestock grazing in hot semi-arid environment is prone to extreme fluctuations in the quantity and quality of feed throughout the year (Martin et al. 2004). Quality of feed, and thus, nutrition is one of the main factors affecting ovulation rate and sexual activity in livestock (Vinoles et al. 2005; Forcada and Albecia 2006). Nutrition modulates reproductive endocrine functions in many species including livestock (Martin et al. 2004; Sejian et al. 2011a). Further, undernutrition affects reproductive functions in ruminants at different levels of the hypothalamus-pituitary–gonadal axis (Robinson 1996; Boland et al. 2001; Chadio et al. 2007). Thermal stress and feed scarcity are the major predisposing factors for the low productivity of ewes under hot semi-arid environment (Martin et al. 2004). High ambient temperature augments the effort by livestock to dissipate body heat, resulting in increased rate of respiration, body temperature, heart beat, and water consumption (Marai et al. 2000). Increased body temperature and respiration rate are the most important signs of heat stress in livestock (Al-Haidary 2004). Further, increase in body temperature is associated with marked reduction in feed intake, redistribution in blood flow, and changes in endocrine functions that negatively affect the productive and reproductive performance of livestock (Averos et al. 2008). In addition, exposure of livestock to elevated temperature decreases body weight, growth rate, and body total solids (Marai et al. 2007). The depleted body condition during periods of energy deficiency also reduces heat tolerance (Minka and Ayo 2009).

1.4 Climate Change and Multiple Stresses Concept

In the present changing climate scenario, there are numerous stresses other than the heat stress which constraint the livestock and have severe consequences on their production (Sejian et al. 2010b). The projected climate change (CC) seriously hampers the pasture availability especially during the period of frequent drought in summer. Thus, livestock suffer from drastic nutrition deficiency. Both the quantity and the quality of the available pastures are affected during extreme environmental conditions (Gaughan et al. 2009). Further, with the changing climate, animals have to walk long distances in search of pastures. This locomotory activity also puts the livestock species under enormous stress (Gustafson et al. 1993; Sejian et al. 2011a). The majority of domesticated ruminants are raised solely or partially in semi-extensive or extensive production systems in which most nutrients are derived from grazed forage. Grazing is associated with daily activities considerably different than for confined animals such as time spent for eating and distances traveled. These activities result in greater energy expenditure (EE) than in confinement, which can limit energy available for maintenance and production. The grazing animals in the tropical areas usually have access to poor quality food available at lower densities per unit area, and to counter such hardship, animals increase their grazing time and disperse widely. Hence its not only the heat stress that needs to be counteracted but the nutrition and walking stress are also of great concern. Though the animals live in a complex world, researchers most often study the influence of only one stress factor at a time. Comprehensive, balanced, and multifactorial experiments are technically difficult to manage, analyze, and interpret (Blanc et al. 2001). When exposed to one stress at a time, animals can effectively counter it based on their stored body reserves and without altering the productive functions (Sejian et al. 2011b). However, if they are exposed to more than one stress at a time, the summated effects of the different stressors might prove detrimental to these animals. Such a response is attributed to animal's inability to cope with the combined effects of different stressors simultaneously (Sejian et al. 2010b; Sejian et al. 2011b). In such a case, the animal's body reserves are not sufficient to effectively counter multiple environmental stressors. As a result their adaptive capabilities are hampered and the animals struggle to maintain normal homeothermy (Sejian et al. 2010b). Moberg (2000) hypothesized that when animals are exposed to only one stress, they may not require the diversion of biological resources needed for other functions. If, however, two of these stressors occur simultaneously, the total cost may have a severe impact on other biological functions. Thus, normal basal functions are drastically affected which jeopardizes production.

1.5 Ameliorative Measures to Counter Environmental Stresses

This volume focuses on developing suitable ameliorative strategies which must be given due consideration to minimize economic losses incurred through impact of environmental stresses on livestock production. Several chapters are specifically devoted to the ameliorative strategies. Specific focus is on the managemental and nutritional strategies which must be adopted to prevent environmental stresses affecting livestock production. Further, an emerging theme of the probable role of pineal gland in relieving heat stress by its endocrine secretion is also addressed. Besides being a neuroendocrine transducer of cyclic photic input, pineal gland also impacts seasonal changes in reproductive capability of many animal species. Apart from this, it has influence on extra reproductive processes, such as pineal-adrenal; pineal-thytorid, and pineal-immune planes. It has antistress and tranquilizing effect, via melatonin. Melatonin has marked effect on several adrenal-cortex secretions and functions during the stress. Other pineal peptides have also been identified having antithermal stress property. Pineal plays an important role in heat stress amelioration in livestock (Sejian et al. 2008; Sejian and Srivastava 2009; 2010a). Pineal gland through its secretions, melatonin and other pineal proteins, was able to reduce heat stress in ruminant livestock (Darul and Kruczynska 2004; Sejian and Srivastava 2010b; Sejian et al. 2011c). Thus interrelated, both adrenal and pineal glands help animal to cope with stressful environment (Sejian and Srivastava 2009, 2010a, b).

Multidisciplinary approaches are required to counter environmental stresses influence on livestock production. There are varieties of options pertaining to animal nutrition, housing, and animal health (Collier et al. 2003). Some of the biotechnological options may also be used to reduce environmental stresses. However, it is important to understand the livestock responses to environment, analyze them, in order to design modifications of nutritional and environmental management thereby improving animal comfort and performance (Sejian and Naqvi 2011). An amelioration strategy must be cost-effective, suitable to the target agro-ecological zone, and provide high returns to farmers implementing it. Nutritional manipulation is one of the principal ways to optimize production during extreme environmental conditions (Martin et al. 2004; Scaramuzzi et al. 2006). Improved nutrition is an important tool to enhance ovulation rate and accentuate the overall reproductive efficiency especially in low input systems prevalent in arid, and semi-arid tropical environment (Archer et al. 2002; Scaramuzzi et al. 2006).

1.6 Adaptive Mechanisms of Livestock

The third section of the volume describes several mechanisms by which the livestock tries to adapt to an adverse environment. It addresses the basic principles that are involved in livestock adaptation to the environmental stresses. It focuses on the neuroendocrine mechanisms that control the process of livestock adaptation, and also deliberates the molecular mechanisms involved in making an animal adaptable to a specific environment. The genetic basis and its significance for livestock adaptation are also addressed in this section. Finally, efforts are made to incorporate information pertaining to identifying genes involved in thermal tolerance of livestock. This section provides an insight into how adaptations are controlled involving various systems of the body including nervous, endocrine, genetic, and molecular level control.

Animals in different parts of the world face different types of environmental factors in the form of temperature, solar radiation, photoperiod, humidity, geographical location, nutrition, and socio-economic signals. Homeostasis is referred to as the relative physiological activity in an organism critical to survival. Regardless of the changes in the environmental conditions, living species attempt to maintain constant core body temperature within a range through a definite set of regulatory behavioral and physiological mechanisms. Each species, breed, or animal category, correlated with its physiological state, has a comfort zone, in which the energy expenditure of the animal is minimal, constant, and independent of environmental temperature. Outside of this zone, the animal experiences stress to maintain homeothermy. Because maintaining homeothermy requires extra energy to thermoregulate, less energy is available for production processes (Nardone et al. 2006). Thus, animals modifies its behavior, especially feeding, physiological, and metabolic functions and the quantity and quality of its production. The extents to which they are able to adapt are limited by physiological (genetic) constraints (Alhidary et al. 2012). Responses of animals vary according to the type of thermal challenge: short-term adaptive changes in behavioral, physiological, and immunological functions (survival-oriented) are the initial responses to acute events, while longer term challenges impact performance-oriented responses (Gaughan et al. 2010). When environmental conditions change, an animal's ability to cope (or adapt) to the new conditions is determined by its ability to maintain performance and oxidative metabolism (Gaughan et al. 2010). The stress response is influenced by a number of factors including: species, breed, previous exposure, health status, level of performance, body condition, mental state, and age. Neuroendocrine responses to stress play an integral role in the maintenance of homeostasis in livestock. There are substantial evidences which suggests that neuroendocrine responses varies with the type of stressor and are specific and graded, rather than 'all or none'. While acute responses bring about survival; chronic responses may result in morbidity and mortality. Both of these responses are integrated via a network of mutual interplay between immune system, central nervous system, and the endocrine system. Infact, it is a network that exists between nervous and endocrine system which coordinate this stress response. An important component of this network is the hypothalamo-pituitary-adrenal (HPA) axis; it consists of 3 components: corticotrophin releasing hormone (CRH) neurons in the hypothalamus, corticotrophs in the anterior pituitary, and the adrenal cortex (Bernabucci et al. 2010). The HPA axis is a critical part of this mesh which is activated by the release of several neurotransmitters and hormones. Further, understanding the cellular dynamics behind the short- and long-term adaptation in the tropical animals is useful in developing mitigatory measures for improving the productivity (Collier et al. 2006). Genetic selection has been a traditional method to reduce effects of environment on livestock by development of animals that are genetically adapted to hot climates. Despite the strong knowledge base about the physiological aspects, the effects of heat stress at the cellular and genetic level are not clearly understood (Basirico et al. 2011). It is the cellular/molecular level at which stress also has its deleterious effects. Thus, the adaptive response is observed at cellular level as well and an insight into the molecular/cellular mechanism of stress relieve is important. As a result of stress, there is an increased number of nonnative conformational proteins with anomalous folding. Heat shock proteins, as we know, are evolutionarily conserved and many of them act as regulator of protein folding and structural functions of proteins. There is presence of common environment-specific response genes, making 18–38% of the genome. These genes induce expression of classical heat shock proteins, osmotic stress protectants, protein degradation enzyme, etc.

Genetic adaptability/improvement is an evolutionary process. Evolution is defined as a ongoing process of adaptation of population of organisms to the changing geological, biological, and climatic environment. Due to innumerable combinations of environmental dynamics, animals have a range of genetic types that can counter a variety of climatic, locational, biological, or other conditions. Any population must therefore be genetically heterogenous to be able to withstand the challenges of the environmental stressors. It is this concept that forms the basis of genetic improvement and which is critical to the livestock farming. Indeed, the livelihood of billions of families around the world depends on the economic returns from the livestock sector.

Functional genomics research is providing new knowledge about the impact of heat stress on livestock production and reproduction. Using functional genomics to identify genes that are regulated up or down during a stressful event can lead to the identification of animals that are genetically superior for coping with stress and toward the creation of therapeutic drugs and treatments that target affected genes (Collier et al. 2006). Given the complexity of the traits related to adaptation to tropical environments, the discovery of genes controlling these traits is a very difficult task. One obvious approach of identifying genes associated with acclimation to thermal stress is to utilize gene expression microarrays in models of thermal acclimation to identify changes in gene expression during acute and chronic thermal stress (Collier et al. 2008). Further, gene knockout models in single cells also allow for better delineation of the cellular metabolic machinery required to acclimate to thermal stress. With the development of molecular biotechnologies, new opportunities are available to characterize gene expression and identify key cellular responses to heat stress. These new tools enable to improve the accuracy and the efficiency of selection for heat tolerance. Epigenetic regulation of gene expression and thermal imprinting of the genome could also be an efficient method to improve thermal tolerance.

1.7 Livestock and Climate Change

The final section of the volume addresses the impact of climate change on livestock production, the latter is adversely affected by detrimental effects of extreme climatic conditions (Gaughan et al. 2009). Climate change is projected to be a major threat to the survival of many species, ecosystems and viability and sustainability of livestock production systems in many parts of the world (King 2004; Frankham 2005; Hulme 2005). Even if to varying extents, all productive traits of livestock are affected by climate. Heat associated with high humidity or drought represents the most stressful constraint for animal (Nardone et al. 2006).

The animals respond to these events by decreasing the feed intake, physiological responses, and production responses like reduction in reproductive efficiency and milk production etc. Consequently, adaptation to and mitigation of detrimental effects of extreme climates have played a major role in combating the adverse impact in livestock production. Whereas the animals can adapt to the hot climate, the response mechanisms are helpful to survival but detrimental to performance. Hence formulating mitigation strategies incorporating all requirements of livestock is the essential need of the hour to optimize productivity in livestock farms.

One of biggest challenges facing animal science is to increase the production in the context of climate change. Animal performance may be limited by adverse climatic focus. The economic impact of climate changes in relation to livestock production are widely reported (St-Pierre et al. 2003; Rosenweig et al. 2007), and several losses are predicted if current management systems are not modified to reflect the shift in climate. Animals that have evolved to survive in adverse conditions are endowed with the following characteristics: high resistance to stress, low metabolic rate, low fecundity, long lives, behavioral differences, late maturing, smaller mature size, and slow rate of development (Hansen 2004; Gaughan et al. 2010). Therefore, selection or use of animals (often indigenous breeds) that are adapted to adverse climates may have lower productivity than those selected for less stressful climates. Hence, it is necessary to select livestock, and use livestock systems (e.g., pasture management) on the basis of projected climatic conditions (Gaughan et al. 2010).

Like people, livestock are both the cause and the victim of the CC. The last section of the book describes the various impacts of CC on livestock production and identifies several mitigation strategies available to reduce the enteric methane (CH_4) emission from livestock. There is a growing interest in decreasing the potential threat of CC by reducing emissions of GHGs into the atmosphere (Moss et al. 2000; Sejian et al. 2011d). The scientific evidence of anthropogenic interference with the climate system through GHG emissions has led to worldwide research on assessing impacts that could result from potential CC associated with GHG accumulation (Sejian et al. 2011d). As ecosystems are sensitive to CC, it is necessary to examine the likely impacts of climate change on various components within ecosystems to provide a comprehensive understanding of the long-term effects. While carbon dioxide (CO_2) receives the most attention as a factor relative to CC, there are other gases to consider, including CH_4, nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Agricultural activities contribute significantly to global GHG emissions, namely CO_2, CH_4, N_2O, and ammonia (NH_3), which are major GHGs contributing to the radiative forcing (IPCC 2001). The global release of CH_4 from agricultural sources accounts for two-thirds of the anthropogenic CH_4 sources (Moss et al. 2000). These sources include rice paddies, enteric fermentation by ruminants (enteric CH_4), biomass burning, and animal wastes (Sejian et al. 2011d). CH_4 is a potent GHG and its release into the atmosphere is directly linked with animal agriculture, particularly ruminant production (Beauchemin and McGinn 2005). It has a global warming potential (GWP) 25 times more potent that of CO_2, making CH_4 one of the most important GHG because of its stronger molar absorption coefficient for infrared radiation and its longer residence time in the atmosphere (Wuebbles and Hayhoe 2002; Forster et al. 2007). In fact, livestock are produced throughout the world, and are an important agricultural product in virtually every country. Globally, ruminant livestock are responsible for about 85 Tg of the 550 Tg CH_4 released annually (Sejian et al. 2011d). Ruminant animals, particularly cattle, buffalo, sheep, goat, and camels produce significant amounts of CH_4 under the anaerobic conditions present as part of their normal digestive processes. This microbial fermentation process, referred to as 'enteric fermentation', produces CH_4 as a by-product which is released mainly through eructation and normal respiration, and small quantities as flatus (Lassey 2007; Chhabra et al. 2009; Sejian and Saumya 2011).

There is mounting awareness worldwide of the necessity to protect the environment by reducing the emission of GHGs. Offering relatively fewer cost-effective options than other sectors, such as energy, transport and buildings, agriculture has not yet been a major player in the reduction of GHG emissions (UNFCCC 2008). Agriculture and livestock are nevertheless poised to play a greater role in post-2012 climate agreements (UNFCCC 2008), and indeed wide ranging policy actions are inevitable (McAlpine et al. 2009). Adapting to CC and reducing GHG emission may require significant changes in production technology and farming systems that could affect productivity. Several opportunities exist for reducing CH_4 emissions from enteric fermentation in ruminant animals (Sejian and Indu 2011). To be considered viable, these emissions reduction strategies must be consistent with the continued economic viability of the producer, and must accommodate cultural factors that affect livestock ownership and management (Sejian et al. 2011d). With high GWP of CH_4, livestock producers can be ideal environmental custodians and adopt environment-friendly practices encumbering the enteric emissions. While meeting consumer demands for livestock production, animal welfare, and social responsibilities encounter issues that challenge the environmental domains. These issues must be recognized in order to be dealt with and resolved. Therefore, in considering ethical animal production practices, special consideration must be given to the impacts of the system on the environment.

1.8 Concluding Remarks

This volume entitled "Environmental Stress and Amelioration in Livestock Production" is targeting primarily the researchers involved in improving livestock production under the changing climate scenario. This state-of-the-knowledge compendium pertains to environmental influence on livestock production. This volume is unique because it addresses numerous issues facing researchers around the world. The information presented is specifically relevant to the impact of environmental stresses to livestock production, and adaptation and mitigation strategies to counter such environmental extremes. World class researchers around the world representing different agro-climatic zones have contributed their knowledge and experiences in this volume. The information presented will enhance understanding of improving livestock production under different agro-climatic zones, especially under the changing climate scenarios.

References

Al-Haidary AA (2004) Physiological responses of Naimey sheep to heat stress challenge under semi-arid environments. Int J Agr Biol 2:307–309

Alhidary IA, Shini S, Al.Jassim RAM, Gaughan JB (2012) Physiological responses of Australian Merino wethers exposed to high heat load. J Anim Sci 90:212–220

Ali A, Hayder M (2008) Seasonal variation of reproductive performance, foetal development and progesterone concentration of sheep in the subtropics. Rep Dom Anim 43:730–734

Archer ZA, Rhind SM, Findlay PA, Kyle CE, Thomas L, Marie M, Adam CL (2002) Contrasting effects of different levels of food intake and adiposity on LH secretion and hypothalamic gene expression in sheep. J Endocrinol 175:383–393

Averos A, Martin S, Riu M, Serratosa J, Gosalvez LF (2008) Stress response of extensively reared young bulls being transported to growing-finishing farm under Spanish summer commercial conditions. Life Sci 119:174–182

Basiricò L, Morera P, Primi V, Lacetera N, Nardone A, Bernabucci U (2011) Cellular thermotolerance is associated with heat shock protein 70.1 genetic polymorphisms in Holstein lactating cows. Cell Stress Chaperones 16(4):441–448

Beauchemin KA, McGinn SM (2005) Methane emissions from feedlot cattle fed barley or corn diets. J Anim Sci 83:653–661

Bernabucci U, Lacetera N, Baumgard LH, Rhoads RP, Ronchi B, Nardone A (2010) Metabolic and hormonal adaptations to heat stress in domesticated ruminants. Animal 4:1167–1183

Blanc F, Martin GB, Bocquier F (2001) Modelling reproduction in farm animals: a review. Reprod Nutr Dev 13:337–353

Boland MP, Lonergan P, O'Callaghan D (2001) Effect of nutrition on endocrine parameters, ovarian physiology, oocyte and embryo development. Theriogenology 55:1323–1340

Brown-Brandl TM, Eigenberg RA, Hahn GL, Nienaber JA, Mader TL, Spiers DE, Parkhurst AM (2005) Analyses of thermoregulatory responses of feeder cattle exposed to simulated heat waves. Int J Biometeorol 49:285–296

Chadio SE, Kotsampasi B, Papadomichelakis G, Deligeorgis S, Kalogiannis D, Menegatos D, Zerwas G (2007) Impact of maternal undernutrition on the hypothalamic –pitutary-adrenal axis responsiveness in the sheep at different ages postnatal. J Endocrinol 192:495–503

Chhabra A, Manjunath KR, Panigrahy S, Parihar JS (2009) Spatial pattern of methane emissions from Indian livestock. Current Sci 96(5):683–689

Collier RJ, Coppola C, Wolfgram A (2003) Novel approaches for the alleviation of climatic stress in farm animals. In: Interactions between Climate and Animal Production. EAAP Technical Series No. 7. Wageningen Academic Publishers, Wageningen

Collier RJ, Stiening CM, Pollard BC, Van Baale MJ, Baumgard LH, Gentry PC, Coussens PM (2006) Use of gene expression microarrays for evaluating environmental stress tolerance at the cellular level in cattle. J Anim Sci 84((E Suppl)):E1–E13

Collier RJ, Collier JL, Rhoads RP, Baumgard LH (2008) Genes involved in the bovine heat stress response. J Dairy Sci 91:445–454

Darul K, Kruczynska H (2004) Changes in selected blood metabolites associated with Melatonin administration in Dairy goats. Folia Biologica (Krakow) 52(3–4):239–241

Dib MG (2010) Strategies for beef cattle adaptation to finishing diets, ractopamine hydrochloride utilization and mature size genetic selection. Master's Thesis in Animal Science, University of Nebraska at Lincoln, USA, pp 1–105

FAO (2006) World agriculture: towards 2030/2050, Interim Report. Rome, Italy

FAO (2009) State of food and agriculture—Livestock in the balance. Rome, FAO

Forcada F, Albecia AJ (2006) The effect of nutrition on the seasonality of reproduction in Ewes. Reprod Nutr Dev 46:355–365

Forster P, Ramaswamy V, Artaxo P, Berntsen T, Betts R, Fahey DW, Haywood J, Lean J, Lowe DC, Myhre G, Nganga J, Prinn R, Raga GMS, Van Dorland R (2007) Changes in atmospheric constituents and in radiative forcing. In: Solomon S et al (eds) Climate change 2007: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Frankham R (2005) Stress and adaptation in conservation genetics. J Evol Biol 18:750–755

Gaughan J, Lacetera N, Valtorta SE, Khalifa HH, Hahn L, Mader T (2009) Response of domestic animals to climate challenges. In: Ebi KL, Burton I, McGregr GR (eds) Biometeorology for adaptation to climate variability and change. Springer, Dordrecht, pp 131–170

Gaughan JB, Mader TL, Holt SM, Sullivan ML, Hahn GL (2010) Assessing the heat tolerance of 17 beef cattle genotypes. Int J Biometeorol 54(6):617–627

Gustafson GM, Luthman J, Burstedt E (1993) Effect of daily exercise on performance, feed efficiency and energy balance of tied dairy cows. Acta Agric Scand 43:219–227

Hansen PJ (2004) Physiological and cellular adaptations of zebu cattle to thermal stress. Anim Reprod Sci 82–83:349–360

Hulme PH (2005) Adapting to climate change: is there scope for ecological management in the face of a global threat. J Appl Ecol 42:784–794

IPCC (Intergovernmental Panel on Climate Change) (2001) Climate change 2001: the scientific basis. Intergovernment panel on climate change. Cambridge, UK, Cambridge University Press

Johnson EO, Kamilaris TC, Chrousos GP, Gold PW (1992) Mechanisms of stress: a dynamic overview of hormonal and behavioral homeostasis. Neurosci Biobehav Rev 16(2):115–130

Karman AG (2003) Neroendocrine adaptation to stress in pigs.CRH and vasopressin in the paraventricular nucleaus. PhD Thesis, Department of animal Science, Wageningen University, The Netherlands

Khalifa HH (2003) Bioclimatology and adaptation of farm animals in a changing climate. In: Interactions between climate and animal production. EAAP Tech Ser 7:15–29

King DA (2004) Climate change science: adapt, mitigate, or ignore? Science 302:176–177

Kleemann DO, Walker SK (2005) Fertility in south Australian commercial Merino flocks: relationships between reproductive traits and environmental cues. Theriogenology 63:2416–2433

Kornmatitsuk B, Chantaraprateep P, Kornmatitsuk S, Kindahl H (2008) Different types of postpartum luteal activity affected by the exposure of heat stress and subsequent reproductive performance in Holstein lactating cows. Reprod Dom Anim 43:515–519

Koubková M, Knížková I, Kunc P, Härtlová H, Flusser J, Doležal O (2002) Influence of high environmental temperatures and evaporative cooling on some physiological, hematological and biochemical parameters in high-yielding dairy cows. Czech J Anim Sci 47(8):309–318

Lassey KR (2007) Livestock methane emission: from the individual grazing animal through national inventories to the global methane cycle. Agric For Meteorol 142:120–132

Marai IFM, Habeeb AAM, Farghaly HM (1999) Productive, physiological and biochemical changes in imported and locally born Friesian and Holstein lactating cows under hot summer conditions of Egypt. Trop Anim Health Prod 31:233–243

Marai IFM, Bhagat LB, Shalaby TH, Abdel-Hafez MA (2000) Fattening performances, some behavioral traits and physiological reactions of male lambs fed concentrates mixture alone with or without natural clay, under hot summer of Egypt. Ann Arid Zone 39(4):449–460

Marai IFM, El-Darawany AA, Fadiel A, Abdel-Hafez MAM (2007) Physiological traits as affected by heat stress in sheep—A review. Small Rumin Res 71:1–12

Marai IFM, Daader AH, Soliman AM, El-Menshawy SMS (2009) Nongenetic factors affecting growth and reproduction traits of buffaloes under dry management housing (in sub-tropical environment) in Egypt. Livest Res Rural Dev 21 (3):1–13

Martin GB, Rogar J, Blache D (2004) Nutritional and environmental effects on reproduction in small ruminants. Reprod Fertil Dev 16:491–501

Maurya VP, Naqvi SMK, Mittal JP (2004) Effect of dietary energy level on physiological responses and reproductive performance in Malpura sheep in hot semi-arid region of India. Small Rumin Res 55:117–122

Maurya VP, Sejian V, Kumar D, Naqvi SMK (2010) Effect of induced body condition score differences on sexual behavior, scrotal measurements, semen attributes, and endocrine responses in Malpura rams under hot semi-arid environment. J Anim Physiol Anim Nutri 94:e308–e317. doi:10.1111/j.1439-0396.2010.01012.x

McAlpine CA, Etter A, Fearnside PM, Seabrook L, Laurance WF (2009) Increasing world consumption of beef as a driver of regional and global change: A call for policy action based on evidence from Queensland (Australia), Colombia and Brazil. Global Environ Change Human Policy Dimensions 19(1):21–23

Minka NS, Ayo JO (2009) Physiological responses of food animals to road transportation tress. Afr J Biotechnol 8(25):7415–7427

Moberg GP (2000) Biological responses to stress. Implications for animal welfare. In: Moberg GP, Mench JP (eds) Biology of animal stress. CAB International, Wallingford

Moss AR, Jounany JP, Neevbold J (2000) Methane production by ruminants: its contribution to global warming. Ann Zootech 49:231–253

Nardone A, Ronchi B, Lacetera N, Bernabucci U (2006) Climatic effects on productive traits in livestock. Vet Res Commun 30(Suppl 1):75–81

Rivington M, Matthews KB, Buchan K, Miller D, Russell G (2009) Investigating climate change impacts and adaptation options using integrated assessment methods. Aspect Appl Biol 93:85–92

Robinson JJ (1996) Nutrition and reproduction. Anim Reprod Sci 42:25–34

Rosenzweig C, Casassa G, Karoly DJ, Imeson A, Liu C, Menzel A, Rawlins S, Root TL, Seguin B, Tryjanowski P (2007) Assessment of observed changes and responses in natural and managed systems. Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK, pp 79–13

Scaramuzzi RJ, Cambel BK, Downin JA, Kendall NR, Khalid M, Gutierrez M, Somchit A (2006) A review of the effect of supplementary nutrition in the ewe on the concentration of reproductive and metabolic hormones and the mechanism that regulate folliculogenesis and ovulation rate. Reprod Nutr Dev 46:339–354

Sejian V, Indu S (2011) Salient mitigation strategies to reduce enteric methane emission from livestock. In: Sejian V, Naqvi SMK, Bhatt RS, Karim SA (eds) NAIP sponsored national training manual on *Carbon sequestration*, *carbon trading and climate change* Division of Physiology and Biochemistry. Central Sheep and Wool Research Institute Avikanagar, Rajasthan, India, pp 118–131

Sejian V, Naqvi SMK (2011) Climate change and sheep production: concept of multiple stresses, adaptation and mitigation strategies to sustain production. In: Sahoo A, Sankhyan SK, Swarnkar CP, Shinde AK, Karim SA (eds) Trends in small ruminant production: perspectives and prospects, Satish Serial Publishing House, Azadpur, Delhi, pp 137–167

Sejian V, Saumya B (2011) Enteric methane emissions in livestock: contributors, prediction, estimations and repercussion. In: Sejian V, Naqvi SMK, Bhatt RS, Karim SA (eds) NAIP Sponsored national training manual on *Carbon sequestration*, *carbon trading and climate change*. Division of Physiology and Biochemistry, Central Sheep and Wool Research Institute, Avikanagar, Rajasthan, India, pp 68–80

Sejian V, Srivastava RS (2009) Effects of melatonin on adrenal cortical functions of Indian goats under thermal stress. Veterinary Med Int. doi:10.4061/2010/348919

Sejian V, Srivastava RS (2010a) Pineal-adrenal-immune system relationship under thermal stress: effect on physiological, endocrine and non-specific immune response in goats. J Physiol Biochem 66(4):339–349

Sejian V, Srivastava RS (2010b) Effects of pineal proteins on biochemical profile, enzyme profile and non-specific immune response of Indian goats under thermal stress. Anim Prod Res Adv 6(1):1–6

Sejian V, Lal R, Lakritz J, Ezeji T (2011a) Measurement and prediction of enteric methane emission. Int J Biometeorol 55:1–16

Sejian V, Maurya VP, Naqvi SMK (2010a) Adaptive capability as indicated by endocrine and biochemical responses of Malpura ewes subjected to combined stresses (thermal and nutritional) under semi-arid tropical environment. Int J Biometeorol 54:653–661

Sejian V, Maurya VP, Naqvi SMK (2010b) Adaptability and growth of Malpura ewes subjected to thermal and nutritional stress. Trop Anim Health Prod 42:1763–1770

Sejian V, Maurya VP, Naqvi SMK (2011b) Effect of walking stress on growth, physiological adaptability and endocrine responses in Malpura ewes under semi-arid tropical environment. Int J Biometeorol. doi:10.1007/s00484-011-0420-y

Sejian V, Maurya VP, Naqvi SMK (2011c) Effect of thermal, nutritional and combined (thermal and nutritional) stresses on growth and reproductive performance of Malpura ewes under semi-arid tropical environment. J Anim Physiol Anim Nutr 95:252–258

Sejian V, Maurya VP, Naqvi SMK, Kumar D, Joshi A (2010c) Effect of induced body condition score differences on physiological response, productive and reproductive performance of Malpura ewes kept in a hot, semi-arid environment. J Anim Physiol Anim Nutr 94(2): 154–161

Sejian V, Srivastava RS, Varshney VP (2011d) Effect of melatonin on mineral and enzyme profile in chemically adrenalectomized goats under thermal stress. Indian Vet J 88(2):18–20

Sejian V, Srivastava RS, Varshney VP (2008) Pineal-adrenal relationship: modulating effects of glucocorticoids on pineal function to ameliorate thermal-stress in Goats. Asian Aust J Anim Sci 21:988–994

Shelton M (2000) Reproductive perfoprmance of sheep exposed to hot environments. In: Malik RC, Razaqque MA, al-Nasser AY (eds) Sheep production in hot and arid zones. Published by the Kuwait Institute for Scientific Research, pp 155–162

St-Pierre NR, Cobanov B, Schnitkey G (2003) Economic losses from heat stress by US livestock industries. J Dairy Sci 86(E Suppl):E52–E77

UNFCCC (2008) Challenges and opportunities for mitigation in the agricultural sector: technical paper. United Nation Framework Convention on Climate Change. Online at http://unfccc.int/resource/docs/2008/tp/08.pdf

Vinoles C, Forsberg M, Martin GB, Cajarville C, Repetto J, Meikle A (2005) Short term nutritional supplementation of ewes in low condition affects follicle development due to an increase in glucose and metabolic hormones. Reproduction 129:299–309

Wuebbles DJ, Hayhoe K (2002) Atmospheric methane and global change. Earth Sci Rev 57:117–210