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Environmental Stress and Amelioration in Livestock Production

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Preface

Homeostasis by definition is the tendency of a system, especially the physiological system of higher animals, to maintain internal stability, through coordinated response of its components to any perturbation or stimulus that would tend to disturb its normal condition or function. Animals interact with the environment in a dynamic manner. Changes in the environment, in other words stress, trigger an equal response from the animals which is known as adaptation. Thus, adaptation is an ongoing process that helps an animal to adjust to the environment. Stress, to an animal, can be physical including climatic parameters such as heat, cold, relative humidity, and changes in oxygen tension with altitude. Alternately, stress can also be physiological due to an infection, nutritional deficiency, and metabolic diseases. Whatever the etiology of stress, an animal always strives to establish a balance that would enhance its survival. However, just survival does not suffice. To be successfully adapted, an animal must survive, produce, and reproduce. Therefore, depending on its physiological status, the effect of stress on an animal varies. Although there are innate adaptive mechanisms that help the animal to overcome stress and establish homeostasis, these adaptive mechanisms can be limiting especially when the animal is being raised for production. Stress can have a serious impact on the health of the animal which in turn can reduce feed intake, feed efficiency, milk or meat production, and fertility. Therefore, as a manager, the farmer has an essential role to play in ameliorating stress in animals. It is precisely in this context that this volume is specifically devoted to several adaptive strategies which elaborate how judicious management practices can help an animal adjust and adapt to any changes in its environment. This in turn helps maintain animal health and productivity.

This volume is specifically prepared by a team of multidisciplinary scientists to be a valuable reference material for researchers as the primary target group for this compendium. In addition, the material contained in this volume is also relevant to teaching undergraduates, graduates, and other professionals involved in livestock production. Given the importance of livestock to the global economy, there is a strong need for a world class reference material on sustainable management of livestock in diverse ecoregions. With uncertain climate involving unpredictable extreme events (e.g., heat, drought, infectious disease), environmental stresses are becoming the most crucial factors affecting livestock productivity. Reference materials pertaining to stress physiology of livestock are scanty and obsolete. By addressing systematically and comprehensively all aspects of environmental stresses and livestock productivity, this volume is a useful tool for graduates and undergraduates in understanding the various intricacies of stress physiology. Further, scholars involved in research concerning livestock and its welfare can make use of this book for conducting high quality research in the field of adaptation physiology of livestock. In addition, this volume can also guide livestock researchers in identifying researchable priorities in adaptation physiology. With information and case studies collated and synthesized by professionals working in diversified ecological zones, the volume attempts to study the influence of the environment on livestock production across global biomes.

This 17-chapter compendium provides readers with an insight into the major stress factors that livestock are exposed to and their influence on livestock physiology and production. An attempt is also made to discuss the innate adaptive mechanisms that animals exhibit to counteract the adverse effects of stress. In addition to the adaptive mechanisms, several management and feeding practices have also been established as tested methods for reduction of stress effects. This book also highlights the challenges the livestock industry faces in maintaining the delicate balance between animal welfare and production. Therefore, this book is a comprehensive resource for researchers to understand stress, stress management, and livestock productivity.

The contributors of the various chapters are world class professionals with vast experience in the chosen field supported by several peer reviewed publications. The Editorial Committee takes this opportunity to thank all the contributors from different parts of the world for their dedication in preparing these chapters, for their prompt and timely response, and for sharing their knowledge and experience with others. The efforts of many others, all of those that cannot be individually listed, were also very pertinent in completing this relevant and important volume.

15 February 2012

V. Sejian
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Abbreviations

°C	Degree Centigrade
°F	Degree Fahrenheit
11-HSD	11-hydoxysteroid dehydrogenase
3β HSD	3-beta-hydroxysteroid dehydrogenase
5-HT	5-hydroxy tryptamine
AAMD	Aromatic-amino-acid-decarboxylase
Ach	Acetylcholine
ACTH	Adrenocorticotrophic hormone
ADG	Average daily gain
ADP	Adenosine di phosphate
AFS	Australian Friesian Sahiwal
AI	Artificial insemination
ALT	Alanine amino transferase
AMZ	Australian Milking Zebu
AnGR	Animal genetic resources
ANPP	Aboveground net primary productivity
ARD	Average relative deviations
AST	Aspartate amino transferase
ATP	Adenosine tri-phosphate
ATPase	Adenosine tri-phosphatase
AVP	Arginine vasopressin
BAT	Brown adipose tissue
BCS	Body condition scoring
BDNF	Brain-derived neurotrophic factor
BMPs	Best management practices
BNST	Bed nucleus of the stria terminalis
bST	Bovine somatotrophin
BW	Body weight
CA	Carbonic anhydrase
Caco-2	Human epithelial colorectal adenocarcinoma cells
CBD	Convention on biological diversity
CC	Climate change

CCK	Cholecystokinin
CD14	Cluster of differentiation14
CDC	Center for disease control
CER	Common environment specific response genes
CFCs	Chlorofluorocarbons
CGRFA	Commission on genetic resources for food and agriculture
CH_4	Methane
CK	Creatine phospho kinase
CL	Corpus luteum
cm	Centimetres
CNS	Central nervous system
CO_2	Carbon dioxide
cox2	Cyclo-oxygenase-2
CPRs	Common property resources
CR	Conception rate
CRF	Corticotropin releasing factor
CRH	Corticotrophin-releasing hormone
d	Day
DA	Dopamine
DBB	Diagonal band of Broca
DBRP	Destruction box recognizing protein
Dd	Distance downward
DE	Digestible energy
Dh	Distance travelled horizontal
dl	Decilitre
DM	Dry matter
DMI	Dry matter intake
DNA	Deoxyribonucleic acid
DNMTs	DNA MethylTransferases
Dw	Dwarfism
EAT	Effective ambient temperature
EB	Energy balance
ECF	East coast fever
ECl	Energy cost for moving on level
ECsl	Energy cost for moving on slope
ECT	Evaporative critical temperature
ECw	Energy cost of walking
EE	Energy expenditure
EI	External insulation
EOPs	Endogenous opioid peptides
EPI	Epinephrine
ER	Estrogen receptor
ERK	Extracellular-signal-regulated kinases
FAnGR	Farm animal genetic resources
FAO	Food and Agriculture Organization

FCE	Feed conversion efficiency
FCR	Feed conversion ratio
FEC	Faecal egg count
FFA	Free fatty acids
F gene	Frizzle gene
FMD	Foot and mouth disease
FR	Free radicals
FSH	Follicle stimulating hormone
FSSF	Farm system simulation framework
g	Gram
G6P	glucose -6-phosphatase
GABA	Gamma amino butyric acid
GDP	Gross domestic product
GE	Gross energy
GGA1	Golgi-localized, gamma adaptin protein
GH	Growth hormone
GHG	Green house gas
GHRH	Growth hormone releasing hormone
GIP	Gastric inhibitory polypeptide
GIS	Geographic information system
GIT	GastroIntestinal tract
GLP-1	Glucagon-like peptide-1
GLUT-1	Glucose transporter 1
GLUT2	Glucose transporter 2
GnRH	Gonadotropin releasing hormone
GPS	Global positioning system
GPT	Glutamic pyruvic transaminase
GPX	Glutathione peroxidase
GR	Glutathione reductase
GSH	Growth stimulating hormone
GVBD	Germinal vesicle breakdown
GVP	Genetic variation pool
GWP	Global warming potential
GxE	Genotype by Environment interaction
h	Hours
H_2	Hydrogen ions
HAL	Halothane (*Hal*) *Genotypes*
HAS2	Hyaluronan synthase 2
HATs	Histone Acyl Transferases
Hb	Hemoglobin
hCG	Human chorionic gonadotrophin
HDACs	Histone deacetylases
HHAA	Hypothalamo-hypophyseal-adrenal axis

HIOMT	Hydroxyindole-O-methyltransferase
HLI	Heat load index
HO-1	Heme oxygenase-1
HP	Heat production
HPA	Hypothalamo-pituitary-adrenal
HPG	Hypothalamo-pituitary-gonadal
HPst	Heat production in standing
HPw	Heat production in walking
HR	Heart rate
hrs	Hours
HS	Heat stress
HSE	Heat shock element
HSE-BF	Heat shock element binding factor
HSF	Heat shock factors
HSP	Heat shock proteins
HSP 70	Heat shock protein 70
ICTP	International Centre for Theoretical Physics
IFSM	Integrated farm system model
IGF-1	Insulin like growth factor-1
IL-1	Interleukin-1
IL-2	Interleukin-2
IPCC	Intergovernmental panel on climate change
IUCN	International Union for the Conservation of Nature and Natural Resource's
IUGR	Intra uterine growth restriction
IVDMD	In vitro dry matter disappearance
IVF	In vitro fertilization
IVM	In vitro maturation
JNK	C-Jun NH_2-terminal kinase
Kcal	Kilo calories
kDa	Kilo daltons
kg	Kilogram
KISS	Keep it simple to be sustainable
L	Litre
LBP	Lipopolysaccharide Binding Protein
LCMS	*Leymus Chinensis* Meadow Steppe
LCT	Lower critical temperature
LD	Lethal dose
LDH	Lactic dehydrogenase
LH	Luteinizing hormone
LPS	Lipopolysaccharides
MA-BE	Marker assisted breeding value estimation
MAPK	Mitogen activated protein kinase
MC	Melanocortin
MCH	Melanin concentrating hormone

MD	Marek's disease
ME	Metabolizable energy
Me3His	3-methyl histidyne
MEm	Metabolizable energy for maintenance
MHC	Major histocompatibility complex
MIG	Management-intensive grazing
min	Minutes
miRNA	Mitochondrial RNA
MLC	Myosin light chain
MLCK	Myosin light chain kinase
MNBs	Molasses nutrient blocks
MPA	Medial preoptic area
mRNA	Messenger RNA
mtDNA	Mitochondrial DNA
MY	Milk yield
N_2O	Nitrous oxide
NAT	N-acetyl-transferase
NDF	Neutral detergent fiber
NE	Norepinephrine
NEB	Negative energy balance
NEFA	Non-esterified fatty acids
NEm	Maintenance energy
NEp	Productive energy
NH_3	Ammonia
NK	Natural killer
NMDA	*N*-methyl D-aspartate
NOS	Nitric oxide synthase
NPP	Net primary production
NPY	Neuropeptide Y
OIE	Office International Epizootics
OVLT	Organum vasculosum lamina terminalis
p85	phosphoinositide-3 kinase
PBMC	Peripheral blood mononuclear cell
PCR	Polymerase chain reaction
PCV	Packed cell volume
PEPCK	Phosphoenolpyruvate carboxy kinase
PGE2	Prostaglandin E2
PI	Phagocytosis index
PI-IUGR	Placental insufficiency and intrauterine growth restriction
PlGF	Placental growth factor
PNMT	Phenylethanolamine *N*-methyltransferase
POF	Premature ovarian failure
POMC	Pro-opiomelanocortin
PP	Pineal proteins
PR	Pulse rate

PRPs	Proline-rich proteins
PSE	Pale, soft and exudative
PSMs	Plant secondary metabolites
PSS	Porcine stress syndrome
PTGR	Post transcriptional gene regulation
PTGS	Prostaglandin-endoperoxide synthase
PUN	Plasma urea nitrogen
PVN	Paraventricular nucleus
PYY	Peptide YY
QTL	Quantitative trait loci
RBC	Red blood corpuscles
REV	Relative economic value
RFI	Residual feed intake
RH	Relative humidity
RNA	Ribonucleic acid
ROS	Reactive oxygen species
rpm	Revolution per minute
RR	Respiration rate
rRNA	Ribosomal ribonucleic acid
RT	Rectal temperature
RT-PCR	Real-time polymerase chain reaction
SA	Surface area
SARA	Subacute rumen acidosis
SCC	Somatic cell count
SF6	Sulfur hexafluoride
SGLT1	Sodium-dependent glucose co-transporter
sHSPs	Small heat shock proteins
SIT	Sterile insect technique
SLC2A3	Reduced expression of glucose transporter 3
SLC5A1	Sodium/glucose co-transporter 1
SNPs	Single-nucleotide polymorphisms
SNS	Sympathetic nervous system
SOC	Soil organic carbon
SOD	Superoxide dismutase
SR	Stocking rate
SRBC	Sheep red blood cells
STRE	Stress response elements
SWL	Seasonal weight loss
T_3	Tri-iodo-thyronine
T_4	Thyroxine
TBE	Tick born encephalitis
TBSPs	Tannin-binding salivary proteins
TDI	Tunica dartos indices
TDS	Total dissolved solids
TER	Trans-epithelial electrical resistance

TH	Tryptophan hydroxylase
THI	Temperature humidity index
TI	Tissue insulation
TLR4	Toll like receptor 4
TMR	Total maintenance ration
TNF-α	Tumor necrosis factor alpha
TNZ	Thermoneutral zone
TRH	Thyrotropin releasing hormone
TSH	Thyroid stimulating hormone
TUNEL	Terminal deoxynucleotidyl transferase dUTP nick end labeling
UCP-1	Uncoupling protein-1
UCT	Upper critical temperature
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VEGF	Vascular endothelial growth factor
VFA	Volatile fatty acids
VFI	Voluntary feed intake
Vit	Vitamins
VMH	Ventromedial hypothalamus
WBC	White blood corpuscles
WFM	Whole farm model
WHO	World Health Organization
WUE	Water use efficiency
ZO-1, ZO-2	Zonula occudens-1 and 2
α-MSH	α-melanocyte stimulating hormone
μg	Micro gram
μm	Micro meter

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

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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).