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Heat Stress and Animal Productivity

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Introduction

Stress is a broad term and is described as the cumulative detrimental effect of a variety of factors on the health and performance of animals. Yousef (1985) defined stress as the magnitude of forces external to the body which tend to displace its systems from their resting or ground state. In view of this, heat stress for the dairy cow can be understood to indicate all high temperature-related forces that induce adjustments occurring from the subcellular to the whole-animal level to help the cow avoid physiological dysfunction and for it to better fit its environment. Environmental factors such as ambient temperature, solar radiation and humidity have direct and indirect effects on animals (Collier et al. 1982). Heat stress occurs in animals when there is an imbalance between heat production within the body and its dissipation. Thermoregulation is the means by which an animal maintains its body temperature. It involves a balance between heat gain and heat loss. Under heat stress, a number of physiological and behavioural responses vary in intensity and duration in relation to the animal genetic make-up and environmental factors. Climatic, environmental, nutritional, physical, social or physiological stressors are likely to reduce welfare and performance of animals (Freeman 1987). Heat stress is one of the most important stressors especially in hot regions of the world. The endeavour by homeotherms to stabilise body temperature within fairly narrow limits is essential to control biochemical reactions and physiological processes associated with normal metabolism (Shearer and Beede 1990). The general homeostatic responses to thermal stress in mammals include reduction in faecal and urinary water losses, reduction in feed intake and production and increased sweating, respiratory rates and heart rates. In response to stress, mammals set physical, biochemical and physiological processes into play to try and counteract the negative effects of heat stress and maintain thermal equilibrium. Adaptation to heat stress requires the physiological integration of many organs and systems, namely, endocrine, cardiorespiratory and immune system (Altan et al. 2003). Direct effects involve heat exchanges between the animal and the surrounding environment that are related to radiation, temperature, humidity and wind speed. Under present climate conditions, the lack of ability of animals to dissipate the environmental heat determines that, in many areas in the world, animals suffer heat stress during, at least, part of the year. Heat stress has a variety of detrimental effects on livestock (Fuquay 1981), with significant effects on milk production and reproduction in dairy cows (Johnson 1987; Valtorta and Maciel 1998). Dairy cattle show signs of heat stress when THI is higher than 72 (Armstrong 1994).

The comfort limit depends on level of production. Animals presenting higher level of production are more sensitive to heat stress (Johnson 1987). Heat stress also lowers natural immunity, making animals more vulnerable to disease in the following days and weeks. The decrease in fertility is caused by elevated body temperature that influences ovarian function, oestrous expression, oocyte health and embryonic development. The biological mechanism by which heat stress impacts production and reproduction is partly explained by reduced feed intake but also includes altered endocrine status, reduction in rumination and nutrient absorption and increased maintenance requirements resulting in a net decrease in nutrient/energy availability for production. Since climate change could result in an increase of heat stress, all methods to help animals cope with or, at least, alleviate the impacts of heat stress could be useful to mitigate the impacts of global change on animal responses and performance. Three basic management schemes for reducing the effect of thermal stress have been suggested: (a) physical modification of the environment, (b) genetic development of less sensitive breeds and (c) improved nutritional management schemes.

Shades are the most simple method to reduce the impact of high solar radiation. Shades can be either natural or artificial. Tree shades have proved to be more efficient. Air moving is an important factor in the relief of heat stress, since it affects convective and, according to air humidity, evaporative heat losses. Where possible, natural ventilation should be maximised by constructing open-sided constructions. Improved systems capable of either cooling the animal directly or cooling the surrounding environment are necessary to better control the animal's body temperature and maintain production in hot and hot-humid climates. With cooling devices, the temperature in the animal sheds may be kept low to cool animal, and THI can be kept around 72. Ration modification can help minimise the drop in milk production that hot weather causes. Decreasing the forage to concentrate ratio (feeding more concentrate) can result in more digestible rations that may be consumed in greater amounts. Among the genetic adaptations that have developed in zebu cattle during its evolution has been the acquisition of genes for thermotolerance and disease resistance. Thus, an alternative scheme to crossbreeding for utilising the zebu genotype for livestock production in hot climates is to incorporate those zebu genes that confer thermotolerance into European breeds while avoiding undesirable genes.

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Foreword

Climate change is the most serious long-term challenge to be faced by farmers and livestock owners around the world, as it is likely to impact livestock production and health. The IPCC predicts that by 2100, the increase in global surface temperature may be between 1.8 and 4.0°C. Even if global temperature increases by 1.5–2.5°C, approximately 20–30% of livestock and animal species are expected to be at risk of extinction. Increased number of thermal stress days with higher temperatures and humidity particularly due to global warming are also likely to favor growth of vectors and pests, challenging the health of livestock. It has been found that the livestock of tropics are more resilient to environmental and climatic stress due to their genotype and capacity to interact with the environment. Buffaloes and high-producing cows suffer most at high ambient temperatures, and severe heat stress often leads to loss in their reproductive and productive performance.

Heat stress negatively impacts livestock performance in most areas of the world, as it reduces milk production in animals with high genetic merit. Strategies to alleviate metabolic and environmental heat loads in high-milk-producing animals particularly during early lactation need to be elucidated and developed. The identification of heat-stressed livestock and understanding the biological mechanism(s) by which thermal stress reduces milk production and reproductive functions is critical for developing novel approaches to maintain production or to minimize the reduction in productivity during hot summer months. Adaptation to heat stress requires physiological integration of many organs and systems, namely, endocrine, cardiorespiratory, urinary, and immune system. Heat stress also lowers natural immunity, making livestock more vulnerable to diseases. Further, the decrease in fertility due to elevated body temperature through its effect on ovarian function, estrous expression, oocyte health, and embryonic development has been established. It is known that during heat stress, activation of the hypothalamic–pituitary–adrenal axis and the consequent increase in plasma glucocorticoid concentrations are the most important responses of the animals to heat stress. As such, a greater understanding is required on mechanisms associated with immune suppression and hormonal changes in high-producing animals.

The supplementation of antioxidants in feed (micronutrients and vitamin E) to high-producing animals, especially during periparturient period, may help in improving the productivity by reducing the stress and risk of mastitis. Knowledge on feeding and eating rhythm and postprandial intake patterns will enable predicting diurnal patterns in rumen, post-rumen, and peripheral nutrient assimilation. These will suggest optimal, suboptimal and unfavorable times of nutrient supply to mammary cells and milk synthesis.

All attempts have to be made to alleviate the heat stress on high-producing animals. A number of animal cooling options are being used as per requirements. Air fans, wetting, evaporation to cool the air, and shade to minimize transfer of solar radiation are used to enhance heat dissipation from animals. Animals in ponds lose heat very fast primarily due to conduction and coefficient of heat transfer to water from skin.

This publication very nicely covers the effect of heat stress on animal production and also suggests various methods for alleviation of heat stress. The improved understanding of the impact of heat stress on livestock will help in developing management techniques to alleviate heat stress on dairy animals. It will also serve as a useful reading material for researchers, teachers, dairy executives, and managers.

I wish them all the best.

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Preface

Thermal stress is a major limiting factor in livestock production under tropical climate and also during summer season in temperate climates. Heat stress occurs when the ambient temperature lies above thermoneutral zone. It was traditionally thought that milk synthesis begins to decrease when the THI exceeds 72, but with increasing milk production, it has been observed that high-yielding dairy cows reduce milk yield at a THI of approximately 68. The animal comfort limit depends on level of production and breed of animal. Animals in higher level of production are more sensitive to heat stress. Different livestock species have different sensitivities to ambient temperature and humidity. The capacity to tolerate heat stress is much higher in zebu breeds of cattle particularly higher temperatures at low relative humidity than crossbreds of taurine breeds. This is mainly due the fact that zebu cattle can dissipate excessive heat more effectively by sweating, whereas crossbreds have relatively low ability to sweat. During hot-humid weather, the thermoregulatory capability of cattle to dissipate heat by sweating and panting is compromised, and heat stress occurs in cattle. The water vapour content of the air plays an important role in determining the capacity to lose heat from skin and lungs. The increasing concern with the thermal comfort of dairy cows is justifiable not only for countries occupying tropical zones but also for nations in temperate zones in which high ambient temperatures are challenging livestock production system. Climate change poses formidable challenges to the development of livestock sector all over the world as it is likely to aggravate the heat stress on livestock, adversely affecting their productive and reproductive performance. Since climate change could result in an increase of heat stress, all methods to help animals cope with or, at least, help alleviate the impacts of heat stress could be useful to mitigate the impacts of global change on animal responses and performance.

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About the Book

This book is on livestock with specific reference to heat stress and its alleviation. The topic is very pertinent in light of the impacts of climate change on livestock production and health. Work related to effect of heat stress on animal productivity, immunity, and hormonal levels is discussed in detail. Heat stress occurs in animals when there is an imbalance between heat production within the body and its dissipation. Thermoregulation is the means by which an animal maintains its body temperature. Under heat stress, a number of physiological and behavioral responses vary in intensity and duration in relation to the animal genetic make-up and environmental factors. In response to stress, mammals set physical, biochemical, and physiological processes into play to try and counteract the negative effects of heat stress and maintain thermal equilibrium.

Adaptation to heat stress requires the physiological integration of many organs and systems, viz. endocrine, cardiorespiratory, and immune system. Heat stress also lowers natural immunity making animals more vulnerable to disease in the following days and weeks. The decrease in fertility is caused by elevated body temperature that influences ovarian function, estrous expression, oocyte health, and embryonic development.

The increasing concern with the thermal comfort of dairy cows is justifiable not only for countries occupying tropical zones, but also for nations in temperate zones in which high ambient temperatures are becoming an issue. Improving milk production is, therefore, an important tool for improving the quality of life particularly for rural people in developing countries. The environmental conditions necessitate reduction of heat stress due to solar radiation and heat.

This book discusses all these aspects in detail. Recent works related to effect of heat stress on animal productivity, immunity, and hormonal levels are also discussed in the book. Information on biological rhythm is also included. The book also discusses the methods for alleviation of heat stress in livestock, especially cows and buffaloes. This book would be a ready reckoner for students, researchers and academia and would pave way for further research.

Contents

Thermoregulation

Contents

Abstract

Body temperature in homeotherms is maintained by the thermoregulatory system within 1°C of its normal temperature under ambient conditions that do not impose heat stress. A rise in the core body temperature also increases heat loss by panting and sweating. These responses are physiological strategies to transfer heat from the cow's body to the environment. In order to maintain homeothermy, an animal must be in thermal equilibrium with its environment, which includes radiation, air temperature, air movement and humidity. The range of temperature within which the animal uses no additional energy to maintain its body temperature is called the thermoneutral zone (TNZ), within which the physiological costs are minimal and productivity is maximum. Temperature–humidity index (THI) is an index for assessment of the potential of an environment to induce heat stress in humans and farm animals. Heat loss via skin is more in cows and heat loss by respiration is higher in buffaloes. This is due to less number of sweat glands in buffaloes. Exposure of the animal to high environmental temperature stimulates the peripheral and core receptors to transmit nerve impulses to the specific centres in the hypothalamus, to help in preventing the rise in body temperature. The specific centres in the hypothalamus are the defensive evaporative and non-evaporative cooling systems, appetite centre and the adaptive mechanisms that cause such reactions. The suppressive impulses

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