Biochemical Changes Associated with Stress in Animals Review

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I. INTRODUCTION

STRESS Stress in animals, whether due to environmental, physical, or psychological factors, can lead to significant biochemical changes. These changes are crucial for understanding the physiological responses to stress, as well as for developing strategies to mitigate its adverse effects. This review explores the biochemical markers and pathways affected by stress in animals, the mechanisms underlying these changes, their implications for animal health and welfare, and various strategies for managing stress.

II. Biochemical Markers of Stress

Several biochemical markers are used to assess stress in animals. These markers include hormones, enzymes, proteins, and metabolites that reflect the physiological state of the animal under stress.

1. Cortisol and Corticosterone: In mammals, cortisol is the primary glucocorticoid hormone released in response to stress. It is produced by the adrenal cortex and plays a critical role in the stress response by regulating metabolism, immune function, and inflammation (Sapolsky et al., 2000). In birds, reptiles, and some mammals, corticosterone serves a similar function as cortisol in the stress response (Moberg & Mench, 2000).
2. Catecholamines: These hormones are released from the adrenal medulla and sympathetic nerve endings during stress. They are involved in the "fight-or-flight" response, increasing heart rate, blood pressure, and glucose levels (Minton, 1994).
3. Glucose: Stress-induced release of cortisol and catecholamines leads to increased blood glucose levels, providing immediate energy for the animal to cope with the stressor (Sapolsky et al., 2000).
4. Lactate During intense physical stress, anaerobic metabolism leads to the accumulation of lactate in muscles and blood, resulting in lactic acidosis (Charmander et al., 2005).
5. Acute Phase Proteins (APPs):C-Reactive Protein (CRP) and Serum Amyloid A (SAA): These proteins are produced by the liver in response to inflammation and stress. Elevated levels of APPs indicate an acute phase response (Chrousos, 2009).
6. Oxidative Stress Markers: Malondialdehyde (MDA) and Glutathione (GSH): Oxidative stress results in the production of reactive oxygen species (ROS), which can damage cellular components. MDA is a marker of lipid peroxidation, while GSH is an antioxidant that helps neutralize ROS (Trevisan et al., 2019).

III. Mechanisms of Stress-Induced Biochemical Changes

The physiological response to stress involves the activation of several interconnected pathways like Hypothalamic-Pituitary-Adrenal (HPA) Axis.The HPA axis is a major regulator of the stress response. Activation of the hypothalamus releases corticotropin-releasing hormone (CRH), which stimulates the pituitary gland to secrete adrenocorticotropic hormone (ACTH). ACTH then stimulates the adrenal cortex to produce cortisol or corticosterone (Sapolsky et al., 2000; Dantzer & Mormède, 1983).

Sympathoadrenal Medullary (SAM) System is responsible for the immediate "fight-or-flight" response. Stress activates the sympathetic nervous system, leading to the release of catecholamines (epinephrine and norepinephrine) from the adrenal medulla (Minton, 1994). Also, Cortisol and catecholamines enhance gluconeogenesis, glycogenolysis, and lipolysis, leading to increased availability of glucose and free fatty acids as energy sources (Charmandari et al., 2005).

Stress-induced cortisol modulates the immune system by suppressing pro-inflammatory cytokines and promoting anti-inflammatory cytokines. This helps prevent excessive inflammation but can also impair immune function (Dhabhar, 2009). The increased metabolic activity during stress leads to the production of ROS. While ROS play a role in cell signaling and defense, excessive ROS can cause oxidative damage to lipids, proteins, and DNA (Packer & Cadenas, 2007).

IV. Behavioral and Physiological Effects of Stress

1. Behavioral Changes:

Stress can lead to significant changes in animal behavior, including anxiety, aggression, reduced social interactions, and altered feeding patterns. These changes can impact the overall well-being of the animal and, in the case of livestock, productivity and profitability (Moberg & Mench, 2000).

2. Physiological Effects:

Cardiovascular System: Stress increases heart rate and blood pressure, which can lead to cardiovascular diseases over time (McEwen, 2007).

Digestive System: Chronic stress can lead to gastrointestinal issues such as ulcers, colitis, and irritable bowel syndrome (Sapolsky et al., 2000).

Musculoskeletal System: Stress-induced tension can result in muscle pain and fatigue (Moberg & Mench, 2000).

Reproductive System: Stress can disrupt reproductive hormones, leading to infertility and reproductive failures (Dantzer & Mormède, 1983).

V. Implications of Biochemical Changes Due to Stress

The biochemical changes associated with stress have significant implications for animal health and welfare:

1. Health Impacts:

a.Chronic stress can lead to metabolic disorders, such as hyperglycemia and insulin resistance, increasing the risk of diabetes (Sapolsky et al., 2000).

b.Immunosuppression due to prolonged cortisol exposure makes animals more susceptible to infections and diseases (Charmandari et al., 2005).

c.Oxidative stress contributes to aging and the development of chronic diseases, such as cardiovascular disease and cancer (Packer & Cadenas, 2007).

2. Reproductive Effects:Stress can disrupt reproductive hormones, leading to decreased fertility and reproductive performance. In livestock, this can have economic consequences (Dantzer & Mormède, 1983).

3. Performance and Productivity:In production animals, stress can reduce growth rates, feed efficiency, and milk yield, affecting productivity and profitability (Moberg & Mench, 2000).

VI. Management of Stress in Animals

To mitigate the adverse effects of stress on animals, several strategies can be employed:

1. Environmental Enrichment: Providing animals with a stimulating and comfortable environment can reduce stress. This includes adequate space, social interactions, and enrichment devices (McEwen, 2007).
2. Nutritional Interventions: Diets supplemented with antioxidants (such as vitamins E and C) can help reduce oxidative stress. Additionally, balanced nutrition supports overall health and stress resilience (Nockels, 1996).
3. Pharmacological Interventions: The use of anxiolytics, anti-inflammatory drugs, and other medications can help manage stress in animals, particularly in clinical settings (Charmandari et al., 2005).
4. Handling and Management Practices: Minimizing stressful handling and transportation practices can significantly reduce stress levels in animals. Training handlers and using low-stress techniques are essential (Moberg & Mench, 2000).
5. Behavioral Therapy and Training: Behavioral modification techniques, including desensitization and counter-conditioning, can help animals cope with stressors. Training animals to be more resilient to stress through positive reinforcement can also be beneficial (Moberg & Mench, 2000).
6. Monitoring and Early Intervention: Regular monitoring of biochemical markers can help detect stress early, allowing for timely intervention and management (Charmandari et al., 2005).

VII. Future Directions in Stress Research

Research in the field of stress in animals is ongoing, with several promising areas of investigation:

1. Genetic and Epigenetic Factors: Understanding the genetic predisposition to stress and the epigenetic modifications that occur due to stress can provide insights into individual variability in stress responses (Charmandari et al., 2005).
2. Microbiome and Stress:The gut microbiome plays a crucial role in the stress response. Research into how stress alters the microbiome and how microbiome modulation can mitigate stress effects is an emerging field (Trevisan et al., 2019).
3. Technological Advances:The development of non-invasive techniques for monitoring stress biomarkers, such as wearable devices that measure physiological parameters, can improve stress management in animals (Keena et al., 2001).
4. Holistic Approaches:Integrating various management practices, including environmental, nutritional, and behavioral strategies, into a holistic approach to stress management can enhance overall animal welfare (McEwen, 2007).

VIII. Conclusion

Biochemical changes associated with stress in animals provide valuable insights into the physiological mechanisms underlying the stress response. Understanding these changes is crucial for developing effective strategies to manage stress and improve animal health and welfare. Continued research in this field will enhance our ability to mitigate the negative impacts of stress and promote better outcomes for animals in various settings, from companion animals to livestock.

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