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Oxidative Stress in Poultry

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In modern day poultry production industries, oxidative stress (OS) is a serious issue that affects the general health of birds. It is distinguished by an imbalance between the generation of reactive oxygen species and antioxidant defense systems. Different environmental, technological, nutritional and biological/internal stresses are found to be associated with modern commercial poultry industry and are the one of major causes for reduced reproductive and productive performance as well as challenges health status of birds. Anti-oxidant defense mechanism includes various enzymatic and non-enzymatic processes. Among genetic, environmental and dietary manipulation approaches to address the OS in poultry, nutritional method is quite effective and practical to optimize production performance in chickens.

Key words: oxidative stress, antioxidants, dietary manipulation, production performance

Introduction

Among various sectors of agriculture, animal husbandry forms major proportion and in it, poultry industry is rapidly growing and continuously expanding thereby considerably contributing to food security and human nutrition. Globally, poultry eggs and meat are frequently consumed animal derived food sources. There has been substantial genetic improvement in birds for more production and adequate nutritional practices are also followed to explore such elite gene make-up. Although production performances are undoubtedly improved but such production capacities make poultry susceptible to various stress agents. Different environmental, technological, nutritional and biological/internal stresses are found to be associated with modern commercial poultry industry and are the one of major causes for reduced reproductive and productive performance as well as challenges health status of birds. During course of evolution, poultry had developed anti-oxidant mechanisms to combat different stress factors. Excessive free radical generation at cellular levels, weak anti-oxidant systems and oxidative stress together affects normal physiology of birds and results in harmful outcomes. Reduced body weight gain, increased feed conversion ratio and overall decrease in production performance appeared to be major detrimental effects.

Rapid weight gain in modern day broilers make them more prone to increasing environmental temperature. Moreover absence of sweat glands, heavy feather covering and considerable body mass to body surface area ratio contributes for susceptibility of birds towards environmental stress agents. Homeothermic nature of poultry bird tries to maintain internal body temperature around 41^{o} C. However, with increasing surrounding temperature above 24^{o} C, normal physiology of chicken body get altered and metabolism gets disrupts.

Worldwide temperature increment leads to oxidative stress in birds. Poultry species are more likely to produce free radicals under stressful situations and their capacity to scavenge free radicals and activate antioxidant enzymes decreases. Since there is close connection between oxidative stress and poultry production, it is critical to comprehend how the two interact.

Oxidative stress (OS)

An imbalance arising between the natural antioxidant defense system and the generation of free radicals results in oxidative stress in cells and tissues, which can culminate in lipid peroxidation, protein degeneration, DNA damage and apoptosis. In essence it is disparity between anti-oxidants and pro-oxidants. There is persistent generation of free radicals or reactive oxygen species (ROS) during normal metabolic process occurring inside cells. Since they are extremely reactive in nature, reacting with macromolecules (DNA, protein, lipid) they alter their functions. Either excess production of ROS or compromised anti-oxidant system results in OS in poultry. Generation of ROS found to be more in elevated stressful environments, contributing to further oxidative damage in cells. One of the primary factors that might negatively impact the quality of poultry meat products and growth of chickens is attributed to OS.

Stressful environmental circumstances cause increased ROS concentrations, which hinders the physiology of chickens to maintain its thermal homeostasis. Furthermore, several studies show that poultry species are more susceptible to ambient temperatures and OS than other animal species due to breeding practices and gene selection for rapid development, increased nutrition utilization and higher egg outputs per head, certain bird species, including broilers, layers and turkeys, are particularly susceptible to oxygen deprivation. It was found that a wide range of protective mechanisms against OS in poultry is systematically controlled and regulated. Depending on the circumstances, the stress response may be triggered over a few minutes to hours, days, weeks, months or even years.

In the commercial chicken industry, there are commonly four main types of stress: internal, nutritional, environmental and technological. These stresses cause negative or detrimental alterations at the molecular/cellular and physiological levels, which ultimately impacts reproductive and productive capabilities of chickens. Vaccination and gut dysbiosis are some of internal stressors. Nutritional stressors include imbalanced diets, mycotoxin contamination, rancid fats, inadequate minerals and vitamins. Commonly encountered environmental stressors are inadequate lightning, ambient temperature and ventilation in poultry house. Stocking density, handling of birds for weighing, transporting and transferring, improper egg storage conditions are technological stressors.

Antioxidant Defense Mechanism (ADM)

In poultry, the Antioxidant Defense Mechanism is essential for preventing the detrimental effects of OS. These defense systems include a wide range of complicated and inter-connected non-enzymatic and enzymatic antioxidants that co-ordinate to balance the body's detoxification of ROS. Since the body cannot withstand excessive ROS, OS sets in when the antioxidant defense system is exhausted which results in damage to DNA, polyunsaturated fatty acids and proteins in the body which culminates in compromised health, body growth and sometimes death of the bird. Glutathione peroxidase (GPX), catalase (CAT), superoxide dismutase (SOD), peroxiredoxins and thioredoxin reductase are examples of enzymatic antioxidants. Superoxide is converted by SOD into H_2O_2, which is subsequently neutralized to water and molecular oxygen by CAT and GPX, lowering the concentrations of noxious ROS. Glutathione, ascorbic acid, carotenoids, tocopherol, CoQ, carnitine, taurine and other non-enzymatic antioxidants can scavenge free radicals by releasing an electron or atom of hydrogen.

Any malfunction in these antioxidants has the potential to hamper the equilibrium between the generation and removal of ROS, leading to OS and possible cell damage in the bird. The key components of the anti-stress approach also include redox signaling, transcription factor (Nrf2) and vitagene triggering, as well as increased manufacture of protective compounds with antioxidant and detoxifying properties. Critical components of the antioxidant defense network comprises apoptosis (natural cell death), autophagy and other processes that deal with injured cells to eliminate them and refrain damages from being passed to other neighboring cells or tissues. An increasing amount of data revealed that the body's antioxidants function as a "team" to furnish adaptive homeostasis against OS. Cooperative interactions occur when one member assists another in doing tasks more effectively to combat OS. Antioxidant defense mechanisms actually are found to exist in every cell compartment.

Mitigation strategies

Environmental approach: Use of cooling equipment to minimize ambient temperature, adequate ventilation for fresh air and to avoid ammonia buildup, sufficient stocking density and embryonic thermal conditioning are few ways to reduce OS in chickens.

Genetic approach: Breeding tactics involve selection and mating of birds having naked neck gene, frizzle gene and candidate gene with marker assisted selection. Producing parental stocks with inherent capabilities to combat OS or factors associated with it can effectively help to face the situation.

Dietary approach: Among several methods, nutritional management sounds to be practical and advantageous to overcome OS. Dietary manipulations, feeding regimes and use of feed additives are commonly practiced tactics in commercial poultry production. Restricted feeding, feeding wet feed and feed removal during extreme ambient temperature can aid to reduce heat load in chicken body. Active chemical compounds or bioactive agents of plants like ginkgo, cinnamon, licorice, moringa, rosemary, thyme, hot red pepper, sweet wormwood, turmeric, black cumin and ginger regulates vitagenes and they support the immune system, reduce corticosterone release, manage heat shock response, scavenge free radicals and improve nutrition, lowers lipid peroxidation, boost the antioxidant defense system, preserve gut health, possess antibacterial activities, regulate blood biochemical characteristics and improve digestibility.

In heat-stress challenged broilers, dietary supplementation of vitamins A, B, D, E and C are found to be fruitful and implicated in up-regulating immune-competence and antioxidant defense system of chickens. Minerals involving potassium, zinc, chlorine, selenium, manganese and chromium assist poultry to regulate OS. Carnitine, betaine and flavonoids/polyphenols addition in poultry diet during adverse conditions proved to be critical nutritional approach for alleviating OS.

Since there is interrelationship and coordination among various anti-oxidant systems of body, it is obvious to assume that dietary supplements containing synergistic combinations of several antioxidant elements will have greater protective effects than individual antioxidants. The optimal efficacy of a combination of antioxidants would result from their distinct yet complementary modes of antioxidant action. For instance, because of their complementary actions at various stages of lipid peroxidation and free radical generation, vitamin E and selenium together can have some additional beneficial effects.

Conclusion

Production of modern day poultry from farm to fork includes an array of stress factors contributing to OS. An increasing amount of data makes it abundantly evident that oxidative stress and excessive ROS generation are the two main negative effects of the majority of prevalent industrial stressors in the chicken production industry. Poultry evolved antioxidant

defense mechanisms in order to thrive in an oxygenated environment. They consist of an intricate web of antioxidants that are produced both inside body and externally supplied. In actuality, the body's antioxidants function as a cohesive unit to preserve the ideal redox balance in each cell and throughout the body. Consequently, creating a system of ideal antioxidant supplements to support developing and productive birds in maintaining their bodies' redox balance and efficient antioxidant defenses is a difficult undertaking. By putting new ideas into practice, such as altering the diet, supplementing with antioxidants, and improving management practices, poultry welfare and productivity may be raised. Nevertheless, more research is needed to comprehend the molecular mechanisms underlying the interactions between vitagenes and other signaling systems as well as transcription factors within the cell in order to limit negative effects of OS in avian species and develop an appropriate adaptive response. An all-encompassing and interdisciplinary approach is needed to handle the complexities of oxidative stress in poultry and to provide reliable and sustainable production systems that benefits poultry welfare as well as ensures food safety for humans.

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