A Review of Natural Plant Extracts in Animal Oxidative Stress (Postprint)

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Abstract

Against the backdrop of transformation and upgrading in animal husbandry and the continuous advancement of standardized, large-scale livestock and poultry farming models, how to reduce and control oxidative stress in animal organisms has become one of the urgent issues to be addressed in China' s animal husbandry. Compared with chemically synthesized drugs, natural plant extracts possess advantages such as high safety and efficacy, and low residues and toxic side effects; as antioxidant stress agents for livestock and poultry, they hold significant research value and development potential in reducing livestock diseases and improving production performance. This article summarizes and reviews the antioxidant stress active components in natural plant extracts and their pathways of action, aiming to provide references for the research and development of natural antioxidant stress active components and antioxidant stress agents for livestock and poultry.

Full Text

Research Progress of Natural Plant Extracts in Animal Oxidative Stress

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Abstract: As China' s animal husbandry industry undergoes transformation and upgrading with the continuous promotion of standardized, large-scale livestock and poultry production, reducing and controlling oxidative stress in animals has become an urgent challenge. Compared with chemically synthesized drugs, natural plant extracts offer advantages of safety, high efficacy, minimal

residues, and low toxicity. As antioxidant stress agents for livestock and poultry, they hold significant research value and development potential for reducing disease and improving production performance. This paper reviews the active antioxidant stress components in natural plant extracts and their mechanisms of action, aiming to provide references for the research and development of natural antioxidant stress agents for livestock and poultry.

Keywords: plant extracts; anti-stress; oxidative stress

The term "stress" was first introduced by Canadian pathologist Hans Selye, who defined it as the sum of non-specific responses produced when an organism encounters abnormal stimuli from internal or external stressors. When animals are subjected to external stimuli, a series of neuroendocrine reactions occur, characterized by sympathetic nervous system excitation and increased secretion of adrenocortical hormones via the hypothalamic-pituitary-adrenal (HPA) axis, leading to functional and metabolic changes in various tissues and organs. Numerous stressors exist in nature, including environmental temperature, radiation, malnutrition, excessive stimulation, and negative emotions. However, not all stress is harmful—stress is an integral part of life, and organismal evolution and development result from the combined effects of various stressors. Only excessively intense stress affects health, induces disease, accelerates aging, and may even cause death.

Research has shown that stress responses increase the production of highly reactive molecules such as reactive oxygen species (ROS). Excessive ROS inevitably disrupts the balance between oxidation and antioxidant systems, resulting in oxidative stress. Under normal conditions, trace amounts of ROS produced during metabolism play positive roles in maintaining cellular function. However, during oxidative stress, excessive ROS induces cellular damage, apoptosis, and necrosis, making oxidative stress a key pathological mechanism underlying many diseases.

1. Overview of Oxidative Stress Research in Livestock and Poultry

With accelerated economic development, improved living standards, increased public concern for food safety, and tightening resource and environmental constraints, intensive farming has inevitably replaced traditional breeding models. Although intensive production facilitates large-scale, standardized output, it readily induces varying degrees of oxidative stress in livestock and poultry due to human-animal interaction, substandard management, unstable feed quality, frequent vaccinations, and high stocking densities, seriously affecting animal health and causing substantial economic losses. Initial research on the causes, processes, hazards, and mechanisms of oxidative stress in domestic animals built upon and expanded human antioxidant stress studies. Currently, stress-related

production problems have become a major factor limiting the rapid development of animal husbandry.

Oxidative stress in livestock and poultry typically reduces feed conversion rates and production performance, causes severe weight loss during transport and pre-slaughter waiting periods, and in young animals results in low survival rates, poor development, and growth stagnation. The adverse effects on production performance, intestinal health, and meat quality are particularly severe. To eliminate the large quantities of free radicals generated during oxidative stress, animals consume substantial amounts of antioxidant vitamins and trace elements, ultimately impairing normal immune system development and reducing disease resistance. Perinatal oxidative stress diverts energy intended for milk and egg production toward antioxidant synthesis, decreasing production efficiency and compromising product quality due to oxidant accumulation. Studies have found that excessive ROS damages dairy cow mammary cells, causing senescence, apoptosis, and mastitis, with persistent oxidative stress further exacerbating mastitis development. Additionally, oxidative stress severely impacts reproductive performance in sows, laying ducks, and breeding chickens. In broiler chickens, oxidative stress significantly reduces jejunal villus height, increases crypt depth, and decreases the villus height-to-crypt depth ratio. Numerous studies have reported oxidative stress effects on meat quality, particularly fat and protein oxidation, with significant negative impacts on post-mortem carcass temperature, pH, color, water-holding capacity, and shear force.

Dietary antioxidants can effectively mitigate these adverse effects. Mandah et al. reported that adding antioxidant substances to sheep diets improves antioxidant status, enhances mutton quality, and extends fresh meat shelf life. Current antioxidants fall into three categories. First, antioxidant enzymes such as superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase (CAT) are specific free radical-scavenging enzymes located in cell and organelle membranes that effectively inhibit lipid peroxidation. However, high costs and strict operational requirements limit their large-scale application in animal husbandry. Second, non-enzymatic synthetic antioxidants include ethoxyquin (EMQ), butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), and vitamins A, E, C, -lipoic acid, and -carotene. While some are used in animal production to prevent nutrient oxidation and reduce oxidative stress, concerns remain regarding dosage, residues, and safety, raising questions about potential consequences similar to those caused by antibiotic misuse. Third, natural plant extracts—including polysaccharides, polyphenols, saponins, and amino acids—offer high biological activity, low toxicity, minimal residues, lower development costs, high added value, and strong market demand, making them a research hotspot for combating oxidative stress in livestock.

2. Research Overview of Natural Plant Extracts' Antioxidant Capacity

The 2015 Nobel Prize in Physiology or Medicine awarded to Chinese scientist Tu Youyou for artemisinin has invigorated natural plant extract research in China, highlighting its importance in medical research. As antioxidants, natural plant extracts demonstrate high antioxidant activity and show tremendous research and application value in protecting against oxidative stress, preventing and treating diseases, and maintaining livestock production performance. Recent studies have increasingly reported on plant extracts for combating oxidative stress in livestock, with active compounds including polysaccharides, polyphenols, peptides, organic acids, amino acids, saponins, and flavonoids.

2.1 Polysaccharides

Polysaccharides are organic macromolecules containing more than ten monosaccharide units linked by glycosidic bonds, widely found in plants and edible fungi. Numerous studies have reported their antioxidant, anti-aging, anti-tumor, anti-inflammatory, and immune-enhancing functions. Polysaccharides exhibit strong scavenging activity against various ROS from physical, chemical, and biological sources. Chen et al. demonstrated that Astragalus polysaccharides protect against exercise-induced stress in mice by enhancing antioxidant enzyme activity and exercise endurance. Chen et al. reported that Hericium polysaccharides promote proliferation and tight junction-related gene expression in porcine intestinal epithelial cells under oxidative stress, alleviating lipopolysaccharide (LPS)-induced damage to intestinal barrier function. Natural plant polysaccharides also protect against oxidative stress by enhancing immune function. For example, Pseudostellaria polysaccharides increase immune organ indices, activate reticuloendothelial system phagocytosis, and elevate serum hemolysin levels to enhance stress resistance. Dioscorea polysaccharides improve hepatic glycogen reserves while reducing serum urea nitrogen and lactate, enhancing physical strength and immune resistance to improve stress tolerance. Research shows that immunomodulatory polysaccharides often contain glucans, pectins, xylans, and mannans, with acetyl and sulfate groups significantly enhancing immunological activity and stress resistance. In summary, natural polysaccharides combat oxidative stress primarily by scavenging free radicals, enhancing endogenous antioxidant enzyme activity, chelating metal ions, and boosting immunity.

2.2 Polyphenols

Polyphenols exhibit antioxidant, anti-aging, lipid-lowering, anti-tumor, and neuroprotective effects against stress-induced neurodegenerative diseases. Widely distributed in nature, these compounds serve as natural plant antioxidants with high efficiency. Most plant polyphenols use phenolic hydroxyl groups as hydrogen donors to effectively scavenge various ROS, while also chelating iron and copper ions that promote ROS generation. For instance, polyphenols from

white tea protect striatal cells against hydrogen peroxide (H O)-induced oxidative stress. Eugenol significantly reduces stress-induced elevations in plasma corticosterone and serotonin, while inhibiting oxidative stress-induced neuronal damage by promoting mitochondrial enzyme complex activity and inhibiting acetylcholinesterase. Jin evaluated resveratrol' s antioxidant effects using an H O -stimulated MAC-T cell model of dairy cow mammary epithelial cell oxidative stress, finding that resveratrol significantly improved total antioxidant capacity and protected against H O -induced oxidative damage, likely through the PI3K/AKT and ERK pathways affecting the Nrf2-ARE antioxidant cascade to regulate redox balance in mammary tissue.

2.3 Saponins

Saponins are important bioactive plant compounds classified as steroidal or triterpenoid saponins based on their aglycone structure. Steroidal saponins are abundant in Liliaceae and Dioscoreaceae, while triterpenoid saponins are common in Araliaceae and Apiaceae. Numerous studies have reported antioxidant activity in saponins from ginseng, Rhodiola, American ginseng, Polygonum cuspidatum, Erigeron, Panax notoginseng, Aesculus, and Bupleurum. Pan demonstrated that Bupleurum saponins optimize rumen fermentation parameters in vitro, and dietary Bupleurum extract effectively alleviates heat stress in dairy cows while improving lactation performance.

2.4 Amino Acids

Amino acids exhibit various biological activities, with substantial research on their anti-stress effects. Taurine, the second most abundant amino acid in mammalian central nervous systems, demonstrates antioxidant, anti-inflammatory, and neuroprotective properties. Wu et al. showed that taurine supplementation in broiler drinking water protects against heat stress by regulating metabolism and enhancing antioxidant capacity, significantly improving heat stress-induced oxidative damage. Reeta et al. used intracerebroventricular streptozotocin (ICV-STZ) to induce cognitive impairment in male Wistar rats, finding that taurine significantly reduced neurological damage and improved cognitive performance in Morris water maze, elevated plus maze, and passive avoidance tests. Theanine, a unique free amino acid in tea, protects the nervous system and resists stress by reducing glutamate release and inhibiting autonomic nervous system and HPA axis excitation. Research indicates theanine significantly inhibits salivary -amylase (sAA) activity during anxiety and stress, providing neuroprotective and neurotransmitter-modulating effects. Chronic stress impairs learning, memory, and cognitive function, with traumatic events causing greater stress responses and neurological disorders. Amino acid active components can protect neurological function by ameliorating cognitive decline caused by neuronal damage.

2.5 Organic Acids

Natural plant extracts containing organic acids also demonstrate strong immunomodulatory and anti-stress activities. Santis et al. reported that active organic acid compounds from Sarcandra glabra significantly improve and stabilize stress-induced immunosuppression in mouse models. As an immunoenhancer, these organic acids enhance natural killer (NK) cell activity and increase lymphocyte numbers during stress, thereby improving stress resistance. Holy basil, a medicinal and aromatic plant, contains ursolic acid—a pentacyclic triterpenoid compound that inhibits corticotropin-releasing hormone receptor 1 (CRHR1) and 11 -hydroxysteroid dehydrogenase 1 (11 -HSD1) activity, reducing stress-induced neurological damage. In summary, organic acids primarily exert anti-stress effects by improving the internal environment, enhancing immune function, and inhibiting oxidative damage, often through synergistic actions, though the specific compositional and structural relationships underlying their bioactivity remain unclear.

2.6 Flavonoids

Excessive free radicals or inadequate clearance can cause cellular damage and contribute to liver disease, diabetes, tumors, and other pathologies. Flavonoids, widely distributed in nature, exhibit anticancer, antitumor, antiviral, anti-inflammatory, and anti-allergic activities largely attributable to their potent antioxidant and free radical-scavenging capacities. As research progresses, flavonoids' antioxidant stress activity has gained increasing attention for livestock applications. Liu et al. demonstrated that pine needle flavonoids significantly improve hepatic antioxidant enzyme activity, reduce malondialdehyde (MDA) content, ameliorate oxidative stress in obese rats, and regulate lipid profiles. Xu found that quercetin enhances viability and antioxidant capacity in heat-stressed dairy cow mammary epithelial cells in vitro, exhibiting anti-heat stress effects. Zhan et al. reported that alfalfa flavonoids protect against apoptosis in heat-stressed dairy cow mammary epithelial cells cultured in vitro. In addition to these compounds, essential oils, glycosides, hormones, and compound plant extracts also demonstrate antioxidant stress activity.

3. Conclusion

Although numerous studies have investigated natural plant extracts for combating oxidative stress in livestock, several challenges hinder in-depth research and practical application, including complex extraction and purification processes, stringent usage and storage requirements, uncertain synergistic or antagonistic interactions between active components, and unclear metabolic pathways and long-term effects. Most products remain in the experimental research stage. Future research should focus not only on individual compound extraction and application but also on interactions among multiple substances, employing advanced techniques such as metabolomics and proteomics to achieve holistic

breakthroughs. With continuous advances in chemistry and engineering, establishing simple, rapid, and cost-effective extraction methods alongside efficient and stable active component synthesis will likely become a major research direction. Economical and efficient natural plant extracts as feed additives will not only address issues like antibiotic misuse and illegal drug additions but also inaugurate a new era of green ecological animal husbandry.

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Note: Figure translations are in progress. See original paper for figures.