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Perspective

Antioxidant Enzyme Responses in Cultured Shrimp Under Environmental and Nutritional Stress

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DESCRIPTION

Shrimp production is strongly influenced by environmental conditions, nutrition, stocking density, water quality, and exposure to infectious agents. During normal physiological activity, shrimp cells continuously produce reactive oxygen molecules as part of respiration, immune activity, and other biochemical reactions. At controlled levels, these molecules participate in cellular signaling and defense. When their production becomes greater than the ability of the organism to control them, oxidative imbalance can develop. This condition can affect proteins, lipids, nucleic acids, cell membranes, and metabolic pathways. Antioxidant enzymes therefore have an important biochemical function in maintaining cellular stability and supporting the physiological condition of cultured shrimp.

Shrimp possess several enzymatic defense systems that work together to control reactive oxygen molecules. Among the most studied enzymes are superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, and glutathione-S-transferase. Each enzyme participates in a particular stage of cellular protection. Their activities can change according to water temperature, salinity, dissolved oxygen, ammonia concentration, feed composition, pathogen exposure, handling, transportation, and stocking density. Measuring these enzymes can provide useful information about the physiological response of shrimp to culture conditions.

Superoxide dismutase is one of the primary antioxidant enzymes investigated in shrimp. During cellular metabolism, superoxide radicals may be generated within mitochondria and other cellular locations. Superoxide dismutase converts these molecules into hydrogen peroxide and oxygen. Although hydrogen peroxide is less reactive than the original superoxide molecule, it can still cause cellular damage when present at excessive concentrations. This means that superoxide dismutase operates together with other enzymes rather than acting independently. Changes in its activity may indicate that shrimp are responding to altered environmental or physiological conditions.

Catalase contributes to the next stage of peroxide control. It converts hydrogen peroxide into water and oxygen, reducing the possibility of peroxide-associated damage to cellular structures. Catalase is particularly relevant in tissues with considerable metabolic activity. In shrimp, enzyme activity may vary among tissues because organs differ in metabolic demand and physiological function. Hepatopancreatic tissue is frequently examined because it performs important functions related to digestion, nutrient processing, energy metabolism, and detoxification. Changes in catalase activity in this tissue can therefore provide useful biochemical information about the condition of cultured shrimp.

Glutathione peroxidase provides another important enzymatic defense mechanism. This enzyme uses reducing equivalents associated with glutathione to convert hydrogen peroxide and certain lipid peroxides into less harmful products. Lipid peroxide formation can affect cellular membranes because membrane lipids are susceptible to oxidative reactions. By reducing peroxide accumulation, glutathione peroxidase contributes to membrane stability and cellular protection. Its activity is influenced by nutritional status because several antioxidant pathways depend on adequate availability of nutrients involved in enzyme synthesis and cellular reducing reactions.

Glutathione reductase supports the glutathione cycle by helping regenerate reduced glutathione from its oxidized form. Reduced glutathione participates in several cellular defense reactions and is an important component of the non-enzymatic antioxidant system. The relationship between glutathione reductase, glutathione peroxidase, and cellular glutathione availability illustrates why antioxidant protection should be assessed as a coordinated system rather than through a single enzyme measurement. A change in one enzyme does not necessarily represent the complete antioxidant condition of an animal.

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Glutathione-S-transferase is also relevant because it participates in the transformation and removal of various reactive compounds. This enzyme family can assist cellular detoxification by linking glutathione with selected chemical substances. In aquaculture environments, shrimp may encounter metabolites, contaminants, feed-derived compounds, and other substances that require biochemical processing. Glutathione-S-transferase activity can therefore provide information about how shrimp respond to chemical and environmental challenges.

CONCLUSION

Understanding antioxidant enzymes in shrimp provides a useful framework for evaluating cellular responses under aquaculture conditions. Superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, and glutathione-S-transferase operate through interconnected biochemical pathways that help control reactive oxygen molecules and maintain cellular function. Their activities are influenced by environmental quality, nutrition, disease exposure, and physiological condition. Careful assessment of these enzymes, together with oxidative damage indicators and water-quality measurements, can improve interpretation of shrimp health and support scientifically informed aquaculture management.