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Toxic effects of sulfide on the energy metabolism and gut health in the Pacific white shrimp, *Litopenaeus vannamei*

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Sulfide is a natural and widely distributed toxicant. It can be commonly found on the interface between water and sediment in the aquatic environment. The Pacific white shrimp *Litopenaeus vannamei* starts life in the benthic zone soon after the mysis stage, an early stage of post larvae. Therefore, *L. vannamei* is inevitably affected by exposure to sulfide released from pond sediment. The toxicity and poisoning mechanisms of sulfide were studied in *Litopenaeus vannamei* from the perspective of energy metabolism, metabolomics, gut health and microbiota. The lethal concentrations of sulfide in *L. vannamei* (LC50) at 24 h, 48 h, 72 h, and 96 h were determined. Sulfide at a concentration of 0, 1/10 (425.5 μg/L), and 1/5 (851 μg/L) of the LC50 at 96 h was used to test the responses of *L. vannamei* for 21 days. The results of the study showed that chronic sub-lethal sulfide exposure could lead to the dysfunction of mitochondrial respiration, as evidenced by the change of cytochrome C oxidase activity, disturbed protein synthesis, enhanced gluconeogenesis, and increased substrate consumption for ATP synthesis. The accelerated tricarboxylic acid cycles could provide extra energy for dealing with sulfide stress. Chronic sulfide exposure could adversely affect the health status of shrimp and therefore lower *L. vannamei* survival. Dose-dependent relationships were found in L. vannamei exposed to sulfide. Also chronic exposure to sub-lethal sulfide could lead to damage of the gut structure, stimulate the response of the inflammatory and immune systems, and shape the microbiota structure in the gut of *L. vannamei*. The microbiota structure includes three aspects. First, the abundance of pathogenic bacteria increased significantly with the increasing concentration of sulfide. Next, the abundance of some anti-stress bacteria decreased. Last, adaptation of sulfide-stimulated bacteria was commonly found and down-regulated.

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