



# Recent Developments in Micronutrient Applications for Sustainable Aquaculture

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## DESCRIPTION

Shrimp aquaculture has become one of the fastest-growing food production sectors worldwide, supporting both economic development and global seafood supply. Optimal nutrition plays a vital role in improving growth, survival, feed efficiency and disease resistance in cultured shrimp. Among the diverse nutritional requirements, vitamins are indispensable micronutrients that act as coenzymes, antioxidants and regulators of metabolic pathways. Over the last decade, a considerable number of studies have examined the role of different vitamins in shrimp health and production.

### Vitamin E as an antioxidant

Vitamin E, particularly in the form of alpha-tocopherol, is one of the most studied vitamins in shrimp aquaculture. It plays a protective role against oxidative stress by preventing lipid peroxidation of cell membranes. Over the past decade, vitamin E supplementation has been linked with improved immune response, enhanced survival under stressful conditions and better reproductive performance in broodstock. Several studies have demonstrated synergistic effects of vitamin E with selenium, indicating a combined role in maintaining antioxidant defense systems. Recommended dietary levels have been refined to balance cost and efficacy, as excessively high doses can sometimes result in diminished growth performance.

### Vitamin K and blood coagulation

Vitamin K contributes to blood clotting, bone metabolism and protein synthesis. Although shrimp have different physiological systems compared to vertebrates, dietary vitamin K supplementation has been shown to reduce mortality rates and improve feed efficiency in recent studies. Vitamin K2

(menaquinone) has received particular attention in aquaculture research, with findings suggesting it enhances bone strength and molting success. During the last decade, research on vitamin K in shrimp has expanded from basic dietary trials to more detailed molecular studies, although data remain limited compared to vitamins A, C and E.

### Vitamin interactions and synergistic effects

Research during the last decade has emphasized that vitamins rarely function in isolation. Instead, synergistic interactions often determine overall effectiveness. For instance, vitamin E works closely with selenium to enhance antioxidant defense, while vitamin C regenerates oxidized vitamin E, maintaining its protective capacity. Similarly, vitamin D interacts with phosphorus and calcium to regulate mineral metabolism. Understanding these interactions has allowed aquaculture nutritionists to refine multivitamin premixes for shrimp diets. Balanced formulations not only improve growth and survival but also reduce feed costs by preventing over-supplementation of individual vitamins.

### Vitamins on immunity and disease resistance

Shrimp farming is frequently challenged by viral, bacterial and parasitic diseases. Over the last decade, nutritional immunology has emerged as an important field of study, highlighting the role of vitamins in enhancing shrimp immunity. Vitamin C and E supplementation, in particular, have been linked with increased phagocytic activity, improved hemocyte counts and reduced mortality during disease outbreaks. Vitamin A and B-complex vitamins also support mucosal defense and enzymatic activity related to immune responses. These findings underline the importance of incorporating vitamins not only for growth but also for maintaining biosecurity in aquaculture operations.

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### Feed technology and vitamin stability

One of the challenges in vitamin nutrition is the instability of certain compounds during feed processing and storage. Heat, oxygen and moisture often degrade vitamins, reducing their effectiveness by the time they are consumed by shrimp. During the past decade, advances in microencapsulation and coated vitamin formulations have improved stability and bioavailability. These technologies ensure consistent vitamin delivery throughout the production cycle. Furthermore, the integration of molecular tools has enabled researchers to better evaluate vitamin absorption and utilization at the cellular level, offering more precise data for diet formulation.

Vitamin nutrition plays a central role in sustaining growth, reproduction, immunity and survival of farmed shrimp. Research from the last decade has significantly advanced understanding of vitamin requirements, stability and functional roles. Fat-soluble vitamins such as A, D, E and K have been shown to regulate metabolic and structural processes, while water-soluble vitamins like C and B-complex contribute to stress resistance and enzymatic functions. The integration of stable vitamin formulations, balanced feed premixes and molecular research tools has strengthened shrimp aquaculture practices. Continued research will ensure that vitamin nutrition remains a cornerstone of sustainable shrimp farming, supporting both productivity and food security.