Health & Welfare

Lipid nutrition of Litopenaeus vannamei

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Dietary supplementations of phospholipids and cholesterol are necessary for juveniles

In the authors' studies, lipid analysis was conducted at Texas A&M University.

Phospholipids and cholesterol are two essential lipids for penaeid shrimp. Yet despite the importance of Pacific whiteleg shrimp (*Litopenaeus vannamei*) to the shrimp-farming industry, information regarding its dietary requirements for phospholipids and cholesterol during the juvenile stage is still limited.

The authors conducted a series of tests to determine these requirements and their interaction for *L. vannamei* in the 0.4- to 0.9-gram size range. Studies also evaluated the active components of soybean lecithin. Tests were carried out in indoor, semi-closed recirculating systems with 8 percent daily water exchange.

Phospholipids and shrimp growth

Phospholipids serve as components of cell membranes; second messengers in cell signaling; sources of choline, inositol, and fatty acids; and mediators of lipid metabolism. Shrimp can synthesize phospholipids, but this biosynthesis generally cannot meet their metabolic requirements during juvenile and younger stages. The necessity for dietary phospholipids, such as soybean lecithin and purified phosphatidylcholine, for optimum shrimp growth and/or feed conversion has been reported in the 1 to 6.5 percent range for various species at different stages.

In our studies, deoiled soybean lecithin (97.6 percent acetone insolubles) was used as a source of phospholipids. The major components of the lecithin were 25.7 percent phosphatidylcholine (PC), 21.7 percent phosphatidylethanolamine (PE), and 8.8 percent phosphatidylinositol (PI). Results showed that dietary phospholipids increased shrimp growth rate significantly, with the growth-enhancing effect influenced by dietary cholesterol.

The calculated level of cholesterol in the basal diet was 0.06 percent. As cholesterol level increased, the phospholipid effect tended to diminish (Fig. 1). Dietary phospholipid requirement for juvenile *L. vannamei* was estimated to be 3 percent at 0.4 percent cholesterol, and up to 5 percent at lower supplemental cholesterol levels.

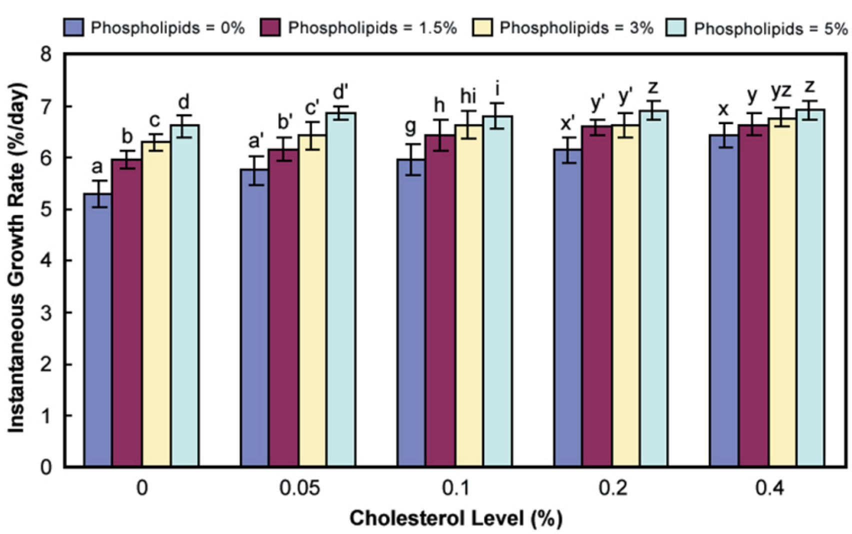

Fig. 1: Instantaneous growth rate values (mean ± SD) of *L. vannamei* fed different levels of cholesterol and phospholipids after six weeks. Significant differences among levels of phospholipids within each

cholesterol level are indicated with different letters (one-way ANOVA by cholesterol level, SNK P<0.05).

Cholesterol

Cholesterol functions as a component of cell membranes, and is important in maintaining membrane fluidity. It is also a major sterol in shrimp, a precursor of steroid hormones, and a component of lipoproteins. Shrimp cannot synthesize cholesterol from acetate and mevalonate, but may possess the ability to dealkylate some C_{28} and C_{29} sterols to cholesterol. Optimal dietary levels of cholesterol for shrimp have been reported as 0.2 to 2 percent, depending on species, stage, and other dietary ingredients.

Our studies indicated that without dietary phospholipid supplementation, 0.35 percent dietary cholesterol was required by *L. vannamei* for maximum growth. Dietary phospholipid had significant effects on cholesterol requirements of shrimp. As the supplemental phospholipid level increased, the dietary cholesterol requirement of shrimp tended to decrease.

An apparent plateau in instantaneous growth rate was reached in response to increasing levels of dietary cholesterol when phospholipid was 1.5 percent of diet or higher (Fig. 2). Broken-line regression analyses showed that, at dietary phospholipid levels of 1.5, 3 and 5 percent, the cholesterol requirements of *L. vannamei* were 0.14, 0.13 and 0.05 percent, respectively.

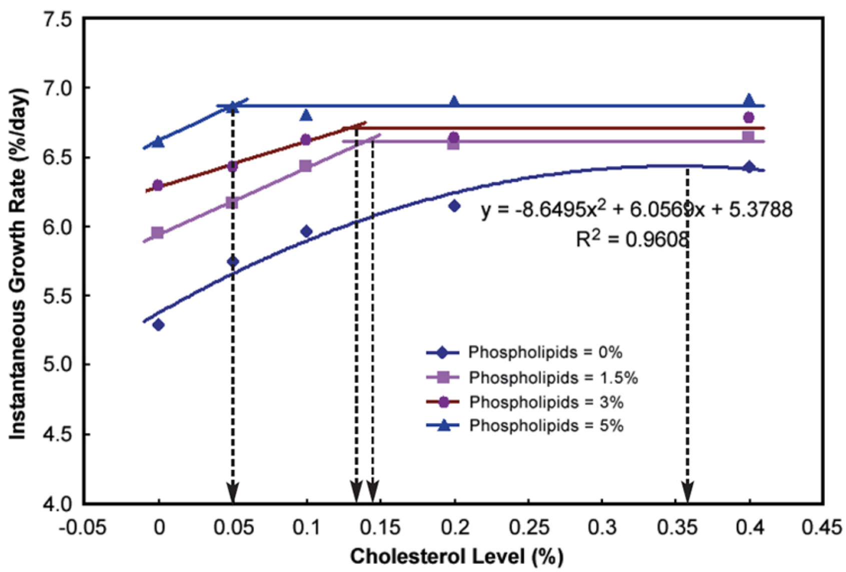

Fig. 2: Effect of dietary phospholipids on cholesterol requirement of *L. vannamei* as measured by instantaneous growth rate.

Interaction between phospholipids and cholesterol

Phospholipids enhance lipid transport and facilitate lipid digestion and absorption in crustaceans. Phospholipids also act as acyl donors for the lecithin-cholesterol acyltransferase, to convert cholesterol to cholesterol ester, implying an interaction between phospholipids and cholesterol.

Results from our six-week growth trial showed a highly significant interaction between dietary phospholipids and cholesterol on growth of juvenile *L. vannamei*. Further biochemical analyses revealed the interactive effects of these compounds on total lipid and triglyceride concentrations in the hepatopancreas, as well as on cholesterol concentration in muscle. A reduction of expensive cholesterol in shrimp diets can be achieved by supplementing soybean lecithin without affecting the shrimp performance.

Active components of soybean lecithin

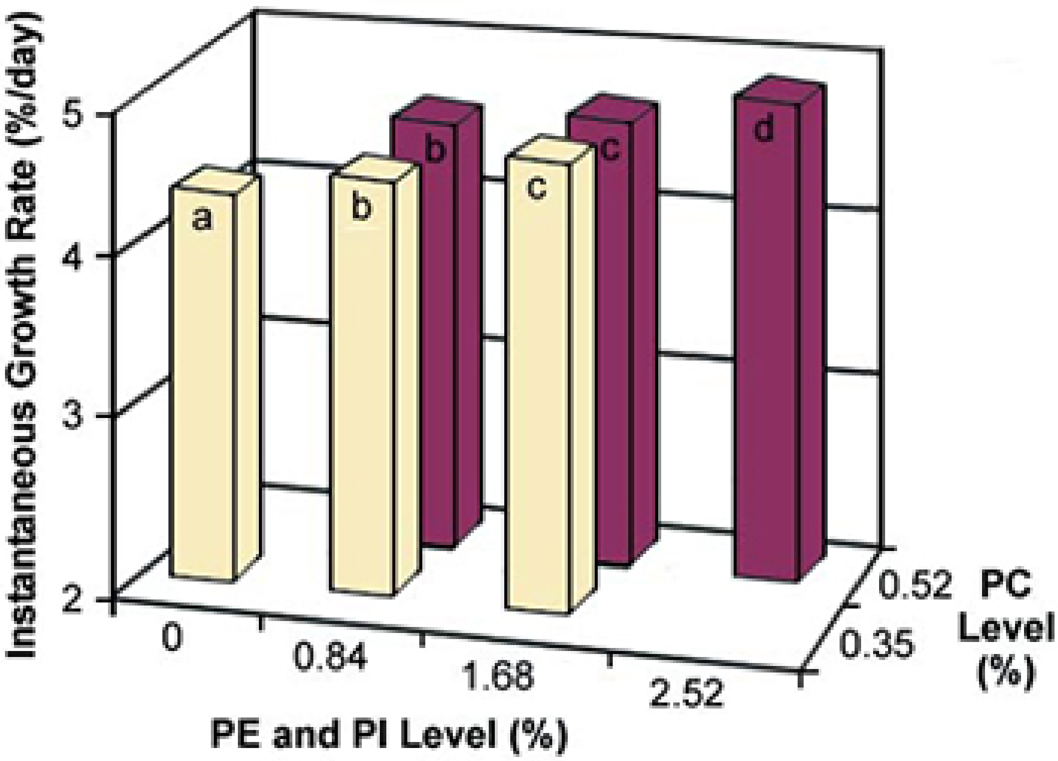

Fig. 3. Effect of dietary phosphatidylethanolamine (PE) and phosphatidylinositol (PI) combined with phosphatidy-lcholine (PC) on shrimp instantaneous growth rate. Significant differences indicated with different letters (SNK P<0.05).

Four major classes of phospholipids are commonly recognized: PC, PE, PI, and phosphatidylserine. Among them, PC is the most abundant phospholipid in animal tissues, and has been assumed to be the major active component in lecithin. Knowledge of phospholipid function and metabolism is mostly based on research of mammals, with relatively few studies done in crustaceans.

Soybean lecithins are widely used for dietary supplementation of phospholipids in shrimp studies because of their industrial availability and beneficial effects on shrimp performance. Identification of active components of soybean lecithin is very important for a better understanding of the role of phospholipids in shrimp nutrition and lipid metabolism.

When diets were supplemented with purified PC (93 percent PC and 3 percent lysophosphatidylcholine) at 0 to 4.2 percent in our studies, no effect was observed on growth and survival of *L. vannamei* juveniles. However, at a certain PC level, PE and PI showed significant growth-enhancing effects (Fig. 3).

Dietary phospholipids and purified PC showed different effects, not only on shrimp growth, but also on lipid content and fraction in shrimp tissues. Diets supplemented with phospholipids resulted in higher total lipid in hepatopancreas and lower total lipid in muscle of shrimp than diets without supplemental phospholipids. In contrast, increasing purified PC in the diets decreased total lipid, free fatty acid level and other phospholipids in hepatopancreas, but did not influence total lipid level in shrimp muscle.

Conclusion

Our studies concluded that dietary supplementations of phospholipids and cholesterol are necessary for juvenile *L. vannamei*. There were interactive effects between phospholipids and cholesterol on shrimp performance.

Cholesterol requirement can be lowered as dietary phospholipid level increases. A combination of 0.05 percent cholesterol and 5 percent phospholipid is recommended for intensive *L. vannamei* culture.

This research raises the possibility of modifying the diet to produce low-cholesterol shrimp, but more studies are needed in this area.

Purified PC alone was nutritionally inferior to soybean lecithin in improving shrimp growth. Dietary PI and PE enhanced shrimp growth. Further studies are needed to investigate PL effects on requirements of fatty acids and lipid-soluble vitamins for shrimp.

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