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Fish Growth and Lipid Metabolism: The Impact of L-Carnitine on Nutrient Utilization and Energy Efficiency

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SUMMARY

L-carnitine is an essential nutrient synthesized from lysine and methionine, supported by vitamin C and other secondary compounds in animals. It plays a key role in lipid metabolism by facilitating the transport of long-chain fatty acids into the mitochondria for β-oxidation, generating energy. Although organisms can synthesize L-carnitine, its supplementation is often required in conditions where lipid concentrations exceed the synthesis capacity. The impact of dietary L-carnitine supplementation on fish has shown varied results, with some studies indicating improvements in growth, feed efficiency, and lipid metabolism, while others report minimal effects. These discrepancies may be influenced by species, growth stages, dietary composition, and environmental factors. Furthermore, L-carnitine supplementation has been linked to protein-sparing effects and improvements in growth performance and feed conversion ratios, particularly at moderate levels (500-1000 mg/kg). However, excessive supplementation may impair growth due to interference with methionine utilization. This review highlights the potential benefits and limitations of L-carnitine supplementation in aquaculture, emphasizing the need for balanced doses to optimize metabolic regulation and growth.

INTRODUCTION

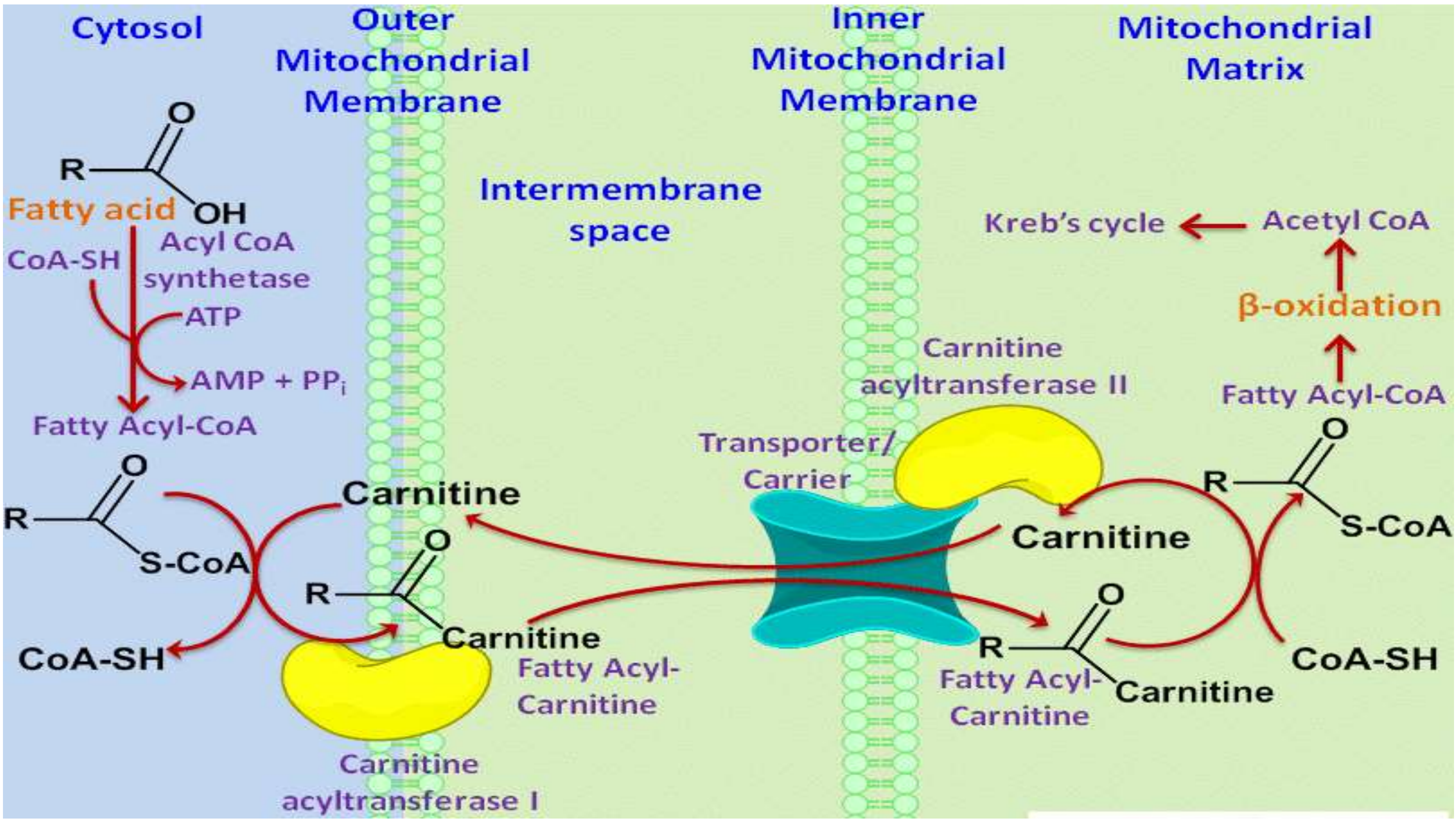
L-carnitine is produced in animals from the necessary amino acids methionine and lysine, with the help of vitamin C and other secondary chemicals that the body produces (Sabzi et al., 2017). Its primary role is to act as a cofactor in the transport of long-chain unsaturated fatty acids to the mitochondrial matrix so that they can be converted into energy through beta-oxidation (Chen et al., 2020). Accordingly, L-carnitine regulates both lipid and energy metabolism (Selcuk et al., 2010; Chen et al., 2020). Although organisms are capable of synthesizing L-carnitine, when the body's lipid concentration surpasses the organisms' capacity to do so, dietary supplementation is typically necessary (Li et al., 2019). Furthermore, the mechanism of L-carnitine synthesis is not well established, which limits the potential of young fish to synthesize L-carnitine (Li et al., 2019). Thus, under certain circumstances, L-carnitine is regarded as an important nutrition for animals.

Since L-carnitine plays a crucial regulatory role in metabolism, adding it to fish feed has garnered a lot of interest due to its potential to enhance growth, increase feed efficiency, and decrease body fat deposition. It has been demonstrated that supplementing farmed fish with L-carnitine increases their yield, which in turn promotes weight gain and feed efficiency while reducing fat deposition (Desai et al., 2010; Zheng et al., 2014). Nevertheless, some research produced inconsistent findings. L-carnitine dietary supplementation changed the liver's lipid metabolism (Gaylord and Gatlin, 2000; Yang et al., 2009). According to the above findings, fish species-specific effects of dietary L-carnitine supplementation were observed. Furthermore, growth stages, feed composition (lipid, protein, lysine, and L-carnitine concentration), and environmental factors (water temperature and quality) may all have an impact on the contradicting results (Ozorio et al., 2012; Li et al., 2019).

The primary determinant of fish development and feed expenses is the protein level of aquatic feed. Fish growth and regular physiological function are largely dependent on dietary lipids, which are the second most important nutrient for aquatic animals after protein. It is commonly recognized that lipids are the primary source of dietary energy and essential fatty acids, and that marine carnivorous fish primarily employ protein as an energy source (López et al., 2009).Consequently, one of the primary methods to lower feed costs is to partially substitute fat for protein.Raising the dietary fat level can save protein and increase feed efficiency within a specific range (Schuchardt et al., 2008; López et al., 2009). On the other hand, fish that consume too much fat may suffer from oxidative stress, immunosuppression, poor development performance, and aberrant lipid metabolism (Xu et al., 2021).

L-carnitine Role Beta oxidation

L-carnitine is essential for controlling fish lipid metabolism since it is the building block for the enzymes carnitine-palmitoyl transferase I (CPT I), CPTII, and carnitine acylcarnitine transferase (CACT). In order to produce energy, it also serves as a transporter to move long-chain fatty acids into mitochondria for β-oxidation (Li et al., 2017). When compared to fish in the wild, fish raised in high-density aquaculture settings may have lower levels of endogenous L-carnitine, which might result in a lack of carnitine to meet metabolic needs and potentially interfere with normal physiological processes (Li et al., 2019).



Impacts on the metabolism of fat L-carnitine needs to be moved to different tissues after synthesis. It is more prevalent in tissues like skeletal and cardiac muscle that primarily rely on fatty acids for energy. By chaperoning activated fatty acids (acyl-CoA) into the matrix and escorting intermediate chemicals out of the mitochondrial matrix to prevent their buildup, l-carnitine contributes significantly to energy production in this respect. Carnitine and its esters are transported across the inner mitochondrial membrane via carnitine-acylcarnitine translocase. As a result, carnitine is a normal component of animal tissues and plasma, which is necessary for the movement of long-chain fatty acids to the oxidation site. Additionally, carnitine helps mitochondria eliminate short-chain organic acids, which frees intramitochondrial coenzyme A to take part in the tricarboxylic acid cycle and h-oxidation pathways. It serves as a substrate for the enzyme carnitine acetyltransferase and carnitine palmitoyl transferases I and II, which are involved in and control the use of fatty acids (Borum, 1987).

Growth performance

- The highest growth performance was observed in fish fed diets containing 500 and 1000 mg/kg of L-carnitine, with weight gain (WG) increasing by 16.57% and 16.41%, respectively, compared to the control group.
- L-carnitine has a positive growth-promoting effect by enhancing nutrient utilization, leading to improved WG, specific growth rate (SGR), and feed conversion ratio (FCR) (Wang et al., 2019; Yang et al., 2012).
- L-carnitine redirects lipids from the body and food to support energy metabolism, contributing to:
- Protein conservation (Tonini et al., 2011).
- Peripheral tissue oxidation and ATP production.
- Transport of long-chain fatty acids across mitochondrial membranes.
- Inhibition of free radical formation, reducing lipid peroxidation and tissue protein aggression (Safari et al., 2015).

- Supplementing young Nile tilapia diets with 450 mg/kg of L-carnitine enabled a 20–30% reduction in protein without affecting growth performance (El-Sayed et al., 2010).
- Long-term administration of high doses (e.g., 2000 mg/kg) of L-carnitine can hinder growth:
- Fish fed 2000 mg/kg of L-carnitine performed similarly to the control group.
- High doses reduce methionine ingestion and utilization, negatively impacting growth and health (Liu et al., 2015; Wang et al., 2019).
- The viscerosomatic fat decreased in fish fed diets containing 1000 mg/kg of L-carnitine due to enhanced oxidation of dietary fatty acids in the mitochondrial matrix (Yang et al., 2009).
- This level of supplementation met energy needs, minimized amino acid catabolism, and promoted growth.
- Fish fed diets with 500 and 1000 mg/kg of L-carnitine showed an increased hepatosomatic index without developing fatty livers:
- Energy from fatty acid oxidation may regulate the glycolytic pathway.
- No accumulation of dietary carbohydrates as visceral fat or hepatic glycogen was observed (Figueiredo et al., 2014).

CONCLUSION

L-carnitine plays a critical role in regulating lipid metabolism in fish, enhancing energy production through β-oxidation and potentially improving growth performance and feed efficiency when included in diets at optimal levels (500-1000 mg/kg). Its effects are species-specific and may vary based on factors such as dietary composition, growth stages, and environmental conditions. Moderate L-carnitine supplementation has been shown to promote better nutrient utilization, protein-sparing effects, and lipid metabolism. However, high levels of supplementation can impair growth and metabolic function, likely due to interference with methionine and fatty acid metabolism. Therefore, careful consideration of supplementation levels is essential for maximizing the benefits of L-carnitine in aquaculture diets.

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