



Fish, Fats, and Hormones: The Secret Chemistry Beneath the Scales

*Naveena T¹, Subash M² and Elakkiya S³

¹PG Scholar, Department of Fish Physiology and Biochemistry, Central Institute of Fisheries Education, Versova, Mumbai, India

²PG Scholar, Department of Fish Genetics and Breeding, Central Institute of Fisheries Education, Versova, Mumbai, India

³PG Scholar, MSc Food Science and Biotechnology, Teesside University, UK

*Corresponding Author's email: tnav1974@gmail.com

There is a misconception among humans that cholesterol and steroids are bad for their health, but in the world of fish, they are one of the pillars of their life. Cholesterol helps cell membranes maintain their shape, keeps nerve tissues from conducting electricity, and is the chemical starting point for steroid hormones. These hormones control metabolism, reproduction, growth and how fish respond to stress. They are the building blocks of fish adaptation and survival. This article outlines of how cholesterol and steroids affect the biological rhythm of fish without their awareness, how they are used in aquaculture, and the problems that synthetic hormones cause for the environment.

Keywords: Cholesterol, Steroids hormones, Fish physiology, Aquaculture, Reproduction

Introduction

Most people associate cholesterol with bad diets or clogged arteries. However, cholesterol is a molecule of life and is not at all a threat to fish. Cholesterol is essential for the flexibility and structure of every cell in a fish's body. It ensures appropriate signal transmission in the nervous system by stabilizing membranes and providing an insulating layer for nerve tissues (Lall, 2002). The liver produces the majority of cholesterol, which is then carried by lipoproteins in the bloodstream. Additionally, fish consumes it as part of their natural lipid intake, which is necessary for growth and health.

The True Effects of Cholesterol Below the Scales

In terms of chemistry, cholesterol is a waxy, yellowish substance composed of hydrogen, oxygen, and carbon (C₂₇H₄₆O). Its structure makes it slightly amphiphilic, meaning it interacts with both fats and water, and it fits snugly into cell membranes. Similar to how oil guarantees smooth motion in a machine, cholesterol maintains the right ratio of rigidity to flexibility inside the cell. It is particularly prevalent in fish tissues found in high-metabolism organs like the brain, gonads, and liver. In addition to its structural function, cholesterol serves as a biochemical "building block." It is transformed into vitamin D, which is required for calcium regulation and bone formation, and bile acids, which aid in the digestion of fat. Most importantly, it is the precursor to steroid hormones, which are small but powerful molecules that act as internal chemical messengers and regulate fish physiology (Mommsen and Walsh, 1988).

Nature's Chemical Factory: From Hormones to Cholesterol

Steroidogenesis is the term for the transformation process that cholesterol initiates inside fish cells' mitochondria. The first step in the synthesis of hormones, pregnenolone is produced

from cholesterol by the enzyme CYP11A1, also known as P450_{scc}. Numerous steroids, including progesterone, testosterone, estradiol, and cortisol, are then produced through a sequence of enzymatic reactions (Nagahama, 1994). Despite their small size, these molecules have a significant impact on fish physiology, affecting everything from growth and metabolism to behaviour and reproduction. The cyclopentanoperhydrophenanthrene nucleus is the structural core of all steroids. All steroid molecules, including sex hormones, stress hormones, and derivatives of vitamin D, are made up of this four-ring structure. A single cholesterol molecule can be converted by the body into a vast array of physiologically active compounds, each of which is uniquely suited to a specific function.

The Hormones That Control Submerged Life

Fish steroids can be roughly divided into two groups: corticosteroids and sex steroids. Estradiol, testosterone, and 17 α ,20 β -dihydroxy-4-pregnen-3-one (DHP) are examples of sex steroids. Estradiol controls female ovulation and egg development, whereas testosterone drives male traits and sperm production. DHP is essential for the last stages of oocyte maturation, which initiates spawning behavior (Nagahama, 1994). The hormones involved in stress management, however, are corticosteroids. The most well-known of these is cortisol, which aids fish in adjusting to environmental stressors like pollution, temperature fluctuations, and salinity changes. Fish can adapt to freshwater and marine environments because cortisol controls energy metabolism and preserves ionic balance. Prolonged cortisol release, however, can impair growth performance and weaken the immune system when stress becomes chronic (Wendelaar Bonga, 1997).

Hormones at Work: Stress, Growth, and Reproduction

Fish use steroids in practically every area of their lives. These hormones increase muscle growth, feed conversion efficiency, and protein synthesis during growth. They regulate the spawning, courtship, and gamete formation times during reproduction. Changes in steroid hormone levels tightly regulate the ability of certain species, like groupers and wrasses, to change sex. The hypothalamic–pituitary–interrenal (HPI) axis is triggered in fish under stress, causing the blood to fill with cortisol. This aids in energy mobilization and homeostasis maintenance. However, the same hormone that once protected the fish can begin to suppress immunity and reproduction if such stress is prolonged—due to poor water quality, handling, or pollution—resulting in decreased productivity and health (Wendelaar Bonga, 1997).

Are Steroids Beneficial or Dangerous for Fish Farming?

Synthetic steroids are now used as a management tool in aquaculture. Farmers commonly use 17 α -methyltestosterone (MT) to create all-male populations of tilapia because males grow and reach market size faster. Prednisolone and dexamethasone are examples of synthetic corticosteroids that are occasionally used to reduce handling and transportation stress. Additionally, some anabolic steroids have been tested to improve feed efficiency and muscle growth. These applications should be used carefully, even though they have the potential to increase productivity. In wild fish populations, synthetic hormone residues that leak into the environment may disrupt hormone balance and lead to abnormal reproduction. Aquatic food webs and biodiversity may be impacted by prolonged exposure to even trace levels of these chemicals (Jobling and Tyler, 2003).

Pollution's Hormone-Like Effects

Beyond aquaculture, pollution poses a covert threat to fish. Endocrine-disrupting chemicals (EDCs) are substances released by industrial chemicals, plastics, and pharmaceuticals. By mimicking natural hormones, they interfere with the fish's endocrine system. Polluted rivers and lakes have been found to harbor fish with mixed sexual characteristics or reduced fertility due to hormonal disruption. In addition to putting individual fish health at risk, these changes have the potential to alter the dynamics of entire populations (Kidd et al., 2007). Fish hormone balance is extremely sensitive, as evidenced by this phenomenon; even a slight alteration in chemical signals can impair growth, reproduction, and survival.

Sustainable Substitutes and a Better Tomorrow

Researchers studying aquaculture are looking into safer and more sustainable ways to preserve fish health and productivity as awareness rises. With the help of selective breeding programs, strains that are naturally fast-growing and stress-tolerant are being created. Examples of dietary supplements that are being used to support natural hormone functions without the need for synthetic intervention include probiotics, essential fatty acids, and amino acids. Chemical treatments are no longer necessary, thanks to developments in genetics and water quality control. These environmentally friendly methods maintain the integrity of aquatic ecosystems in addition to safeguarding fish health. By striking a balance between environmental responsibility and productivity, they represent the future of sustainable aquaculture.

Hidden Congruity Beneath the Scales

Together, cholesterol and steroids keep fish alive despite their unappealing appearance. Steroids supply the signals that guide development, reproduction, and adaptation, while cholesterol builds and protects every cell. Rather than being enemies, these molecules are silent allies in the fight for survival. By understanding their roles, scientists and fish farmers can ensure safer environments, more sustainable production systems, and healthier stocks. Beneath their glistening scales, every fish has a biochemical symphony that is directed by cholesterol and steroids, nature's own orchestra of life.

References

1. Jobling, S., & Tyler, C. R. (2003). Endocrine disruption in wild freshwater fish. *Pure and Applied Chemistry*, 75(11–12), 2219–2234.
2. Kidd, K. A., Blanchfield, P. J., Mills, K. H., Palace, V. P., Evans, R. E., Lazorchak, J. M., & Flick, R. W. (2007). Collapse of a fish population after exposure to a synthetic estrogen. *Proceedings of the National Academy of Sciences*, 104(21), 8897–8901.
3. Lall, S. P. (2002). The minerals. In *Fish Nutrition* (3rd ed., pp. 259–308). Academic Press.
4. Mommsen, T. P., & Walsh, P. J. (1988). Vitellogenesis and oocyte maturation in fish: a review. *Fish Physiology and Biochemistry*, 6(1), 35–54.
5. Nagahama, Y. (1994). Endocrine regulation of gametogenesis in fish. *International Journal of Developmental Biology*, 38(2), 217–229.
6. Wendelaar Bonga, S. E. (1997). The stress response in fish. *Physiological Reviews*, 77(3), 591–625.