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Hormones in Aquaculture: Impacts, Analytical Methods and Future Trends

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SUMMARY

Hormones are used in aquaculture to increase fish production by introducing exogenous hormones into the body that mimic the natural hormones synthesized by the body. These hormones need to be handled carefully as they may leach into the environment or as residues in the fish meat and can impact adversely to the environment as well as the human health by disrupting the endocrine system. This review aims to bring into the view the use of hormones in fish farming, its possible impacts on the environment and the human health, current analytical methods for hormone residues and possible alternatives to hormones in aquaculture.

INTRODUCTION

Aquaculture is the fastest-growing food production sector producing more than half of all the fish consumed by humans and is becoming a vital component of the global economy to feed the rising world population. The per capita consumption of aquatic food annually worldwide increased from 9.1 kg in 1961 to 20.7 kg in 2022. According to FAO, 162.5 million tons of aquatic animal meals were consumed globally in 2021. This statistic has increased nearly twice as quickly as the world's population since 1961. Directing towards continuing the current level of per head consumption, comprehensive aquaculture production needs to attain eighty million tonnes by 2050 (de Bruijn et al., 2017). Hence, incorporating new technologies that allow increasing the number of cultivable species is crucial. For a number of years, the aquaculture industry has mostly concentrated on determining the minimal needs for the various species' growth, development, and ability to reproduce. Teleost fish endocrinology research has proven essential to comprehending how hormones act in biological systems (Gabilondo *et* al., 2022).

Hormones

What are hormones?

Hormones are chemical messengers that are responsible for the communication between different types of cells that recognize their identity and function through receptors, which are protein structures specialized in molecular recognition. Following the hormone-receptor connection and proximity, a sequence of biochemical events takes place that result in particular biological reactions (Reis-Filho, de Araújo, & Vieira, 2006).

Role of Hormones in Fish

Hormones play an important role to perform metabolic activities such as growth, reproduction and to maintain body homeostasis during stress. The hormones responsible are:

a) Growth Hormones: Somatotropin and Thyroid Hormones.
b) Reproductive Hormones: GnRH (Gonadotropin Releasing Hormone), GtH (Gonadotropin Hormone), Estrogen and Androgen.
c) Stress Hormones: Corticosteroid and Catecholamines.

Application of Hormones in Aquaculture

Sex Reversal

Sex reversal in aquaculture is done to obtain a desired monosex population for commercial purposes as it is advantageous to rear individuals of the most profitable gender, thereby achieving more uniform lots and controlling undesirable breeding (Singh, 2013; Taranger *et* al., 2010).

There are two methods for producing monosex fish populations:

- Direct: The target fishes are treated with hormones for the purpose of developing the desired sex.
- Indirect: The parents or breeders are treated with hormones to obtain monosex offsprings.

Some of the hormones used for sex reversal and differentiation in different species of fishes are 17ß-Estradiol, 17α-Ethynylestradiol, 17α-methyltestosterone and 17α-Ethynyltestosterone.

The mode of administration of hormones for sex reversal treatment:

- Systemic (Direct injection and silastic implantation)

- Immersion
- Dietary supplementation (hormone incorporated feed)

Artificial Breeding

Another use of hormones in aquaculture is in seed production, i.e. artificial reproduction, which is important for manipulating the final maturation and ovulation in the gonad. Exogenous hormones can be introduced into the fish to induce/advance or delay/arrest fish maturation and in making fish spawning occur a few months earlier or later than normal. This gives flexibility to farmers in producing and marketing fish seeds when profitability is higher. In addition, this technique is important for the reproduction of fish that need external stimuli and have difficulty in producing in captivity. The technique of induced breeding first evolved in Argentina after producing pituitary extract by B.A. Houssay in 1930. Brazil was the first country to develop a technique for hypophysation in 1934. Later Linpe method was developed by Canadian and Chinese researchers Lin, Hao-Ren and Peter, R.E. in 1988. This method induces ovulation in female fish by injecting them with a combination of a synthetic gonadotropin-releasing hormone analogue (LHRN-A) and the drug domperidone. The hormone stimulates the sex organs of the fish, while the drug inhibits the action of dopamine, a substance produced by the fish that inhibits ovulation. This new method not only prevents sacrificing brooders to produce pituitary extract but also reduces the cost of production, increases the supply of seed fish, and is more convenient.

Hormones used for induced breeding:

- Natural Hormones: Pituitary Extract (Carp, Catfish, etc), hCG (Human Chorionic Gonadotropin), PMSG (Pregnant Mare Serum), etc.
- Synthetic Hormones (GnRHa + dopamine antagonist): Ovaprim, Ovatide, Ovopel, WOFA-FH, etc.

Mode of administration of hormones for induced breeding are generally done through injection (intramuscular or intraperitoneal) in broodstocks.

Impacts of Hormonal Use

Natural hormones used in aquaculture gets introduced into the environment by incorrect or illegal discard of water containing residues of these compounds used to treat fish. The contamination could have originated from by fish excretion, as well as from the medicated feed that remains unconsumed by fish.

Environment Concern

a. Ecological disruption: Hormone residues from synthetic steroids used in fishes can disrupt ecosystems by altering reproductive cycles and behaviours in aquatic life. They may also alter the offspring ratio, inhibition of the development of sexual organs and cause sex reversal.

b. Bioaccumulation: The residual hormones present in water and soil can bioaccumulate in organisms over time and may impact organisms at different trophic levels, potentially affecting the food chain.

Human Health Risk

a. Endocrine disruption: Meat or water contaminated with residual hormones can interfere with the human endocrine system, causing disorders such as early puberty in children, modification of sexual characteristics and cancer development (Bergman *et* al., 2013).

Analytical Methods for Determination of Hormone Residues

Some of the methods to analyse hormone residues are given below:

a. Immunoassays: RIA (Radioimmunoassay) and ELISA (Enzyme Linked Immunoassay)

b. Liquid Chromatography (LC) + detectors
    - LC-UV/Vis (LC – ultraviolet – visible spectrophotometry)
    - LC-fluorescence
    - LC-DAD (LC – ultraviolet diode array)
    - LC-MS/MS (LC – tadem mass spectrometry)

c. GC-MS (gas chromatography – mass spectrometry)

d. HPLC (High Performance Liquid Chromatography)

Immunoassays, such as radioimmunoassays (RIA) and enzyme-linked immunosorbent assays (ELISA), are typically used as analytical techniques for identifying hormone residues (Zanardi, 2007). GC-MS permits simultaneous determination of many analytes with detection limit in the order of ng kg^{-1} or ng L^{-1}, but the sample preparation is laborious and time consuming. Liquid chromatography (LC) coupled to a tandem mass spectrometry (LC–MS/MS) system is currently the recommended analytical technique for quantitative determination of hormone residues in fishery products due to its high specificity and detectability in determining the residue levels of contaminants in complex matrices.

Future Trends in Hormonal Use in Aquaculture

Alternative Hormone Sources

Plant extracts: Some studies have shown that extracts from certain plants (e.g. ginseng) can have beneficial effects on growth and reproduction, acting as natural stimulants (Mehrim *et* al., 2022). Phytohormones such as saponins and flavonoids, have been shown to influence the hypothalamus-pituitary-gonad axis, which is crucial for reproductive functions in fish. These compounds can enhance steroid synthesis and modulate endocrine responses, potentially improving spawning rates and overall reproductive success (Chakraborty *et* al., 2014). While promising, the application of phytohormones in aquaculture is still under research, and their efficacy can vary based on species and environmental conditions.

Genetic Solutions

Selective breeding: Breeding programs focused on selecting for desirable traits such as growth rate, disease resistance, and reproductive performance can reduce the need for hormone treatments.

Precision Aquaculture

*Predictive Analytics***:** AI algorithms analyse large datasets from various sources (e.g., water quality, fish growth rates, feeding patterns) to predict optimal hormone application times and dosages.

Machine Learning Models: These models can identify patterns and correlations that help farmers make data-driven decisions about when and how to administer hormones.

CONCLUSION

In conclusion, while the use of hormones in aquaculture can be beneficial for sex reversal and artificial reproduction, improving the profitability for farmers, improper handling or discarding of residues can pollute the environment as well as impact the human health by interfering the endocrine system. Alternatives like using plant extracts, selective breeding and incorporating AI technology to aquaculture can, if not, replace hormones, reducing possible health risks and concerns of customers. Analytical methods like Immunoassays and Liquid Chromatography (LC) coupled with detectors are widely used of which LC coupled to MS in tandem is one of the best alternatives due to its high precision and sensitivity to determine residual hormones over shorter analyses time.

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