

Role of Pheromones in Aquaculture and Recent Advancements

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Introduction

Pheromones are natural chemical substances generally used for communication between animals. In fish, pheromones play roles in fish aggregation, shoaling, social interactions, kin recognition, prey detection, migration and signalling the presence of predators, individual identification, group cohesion, territorial markings, sex attraction, and synchronization of reproductive processes. Pheromone molecules used by aquatic animals are water-soluble and their diffusion rate can be 10,000times lower than in the air.

Different fish pheromones

Pheromones are structurally identified as a variety of low-molecular-weight metabolites, such as bile salts, F-series prostaglandins, amino acids, and gonadal steroids.

- ❖ **Sex steroids.** They are hormones produced from cholesterol and found in gonads (ovaries or testes). It includes estrogens, androgens, and progestogens. Estrogens possess an 18-carbon estrane skeleton, androgens possess a 19carbon androstane skeleton, and progestogens a 21-carbon pregnane skeleton. These steroids and their derivatives act as reproductive pheromones in many teleost fishes. In Goldfish (*Carassius auratus*), sex steroids and prostaglandins, help inter- and intra-sexual behaviours during reproduction.
- ❖ **Prostaglandins.** Prostaglandins are group of lipids, derived from arachidonic acid. There are 4 series namely, Eseries, I-series, D-series, and Fseries. In some fishes, female uses F-series prostaglandins to trigger sexual behaviour and leak prostaglandins into the water immediately a over ovulation.
- ❖ **Bile salts.** They are diverse group of steroids derived from cholesterol in vertebrates. The bile salt's structural diversity includes 27-carbon bile acids, 24-carbon bile acids and 27-carbon bile alcohols each with C-3, C-7 or/and C12 hydroxylation. The 27-carbon bile alcohols predominate in lampreys, hag fish, cartilaginous fishes and

amphibians, and 27-carbonbile acids in reptiles and early evolving birds. Bile salts are act as a potent odourants for many fishes. Bile salts can be sensed by Arctic char (*Salvelinus alpinus*) and other salmonids that help in migration. However, the role of the bile acid as sex pheromone in sea lamprey, discovered through bioassay-guided fractionation, underscores the unpredictability of nature.

- **Other identified Fish pheromones**

- **Tetrodotoxin (TTX, 1)** - It is a potent neurotoxin. It attracts sexually mature males in grass pufferfish (Fugu niphobles), upon release with ovulated eggs into the water.
- **Tetrahydrofuran diols [petromyroxols and isopetromyroxols]** are potent odourants released by larval sea lamprey, indicating fatty acids may also function as pheromones.

Migratory pheromones

Juvenile salmon become imprinted to odorants of abiotic or biotic origin innatal streams, including small inorganic ions such as calcium and larger organic compounds associated with microbial decay or pheromones. Adult sea lampreys (*P. marinus*) locate spawning streams using a pheromone released by stream-resident larvae Petromyzonol sulfate and allocholic acid.

Sex Pheromones

Chemical compound act as sex pheromones	Fish species
Etiocholanolone glucuronide (male pheromone)	Black goby
Steroid glucuronides (female sex pheromones)	Zebrafish (<i>Danio rerio</i>)
Steroids and prostaglandins	Salmoniformes, Perciformes, Cypriniformes, Characiformes, Siluriformes, Elopiformes, Osmeriformes
Molting hormone 20-hydroxyecdysone	Decapod species
Male-attracting pheromone (L-kynurenine from urine)	Mature female masu salmon (<i>Oncorhynchus masou</i>)
3 keto-petromyzonol sulfate, 3kPZS	Sea lamprey
17 β -Estradiol glucuronate	Mozambique Tilapia

Recent research and development

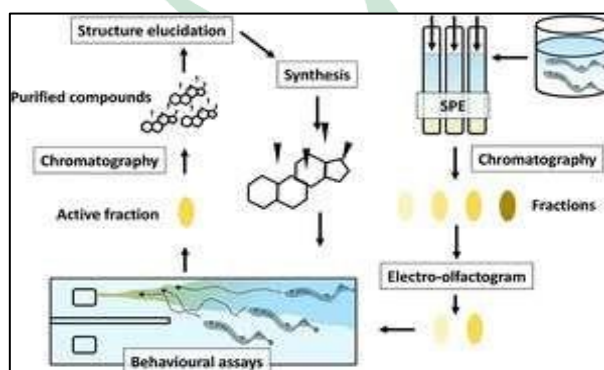
Pheromone based feed ingredients

The application of crab urine and freshwater prawn green gland extracts in freshwater prawn showed good results as an attractant only with males, so it could be recommended for monosex cultures (Mendoza et al., 1997). The application of the feeding stimulant produced a 17 percent increase in the average weight of the tilapia compared to the control pond. There was also an increment in growth of catfish, crucian carp and shrimp.

Sole pheromones

Senegalese sole (*Solea senegalensis*), has good demand in the aquaculture industry. But the problem is that depending on male from wild. During reproduction there is a communication gap between the sexes. But pheromones can help to rectify this issue. The olfactory system of sole is high sensitive to both urine and faeces, those are identified as vehicle for pheromone. There is an increase in FSH level in males after recognising urine of females. But the production and release of pheromones depend on sex and reproductive status.

- ❖ **An amino acid helps in searching of maltes in masu salmon:** Female masu salmon (*Oncorhynchus masou*) release a pheromone in their urine that attracts males. The active component was not either steroid or prostaglandins, active component of the female pheromone is an amino acids. L-kynurenine as pheromone from deep sea fish *Stylephorus chordates*.
- ❖ **Chondroitins elicit alarm responses in zebrafish:** Bioassay-guided fractionation indicates glycosaminoglycan (GAG) chondroitin is a component of a mixture that elicits an alarm response in zebrafish.
- ❖ **Chemical cues and pheromones in the sea lamprey (*Petromyzon marinus*):** Sea lamprey use chemical cues and pheromones to identify productive spawning habitat, coordinate spawning behaviors, and avoid risk. Sea lamprey (*Petromyzon marinus*), which relies heavily upon olfaction during reproduction (Buchinger et al., 2015).
- ❖ **Cortisol as chemical alarm in zebrafish *Danio rerio*:** This study showed that zebrafish *Danio rerio* exposed to chemical alarm cues responded antipredator behaviours – dashing movement and shaol near bottom of the tank. Enzyme-linked immunosorbent assay (ELISA) revealed levels of cortisol in whole body were significantly higher in fish exposed to alarm cues (Barkhymer et al., 2019).
- ❖ **Natural products as pheromones in fish:** Some Biologists have characterized and screened available compounds in pheromones based upon their physiological function. This technique has proven to study pheromones in fish. This was also led by natural product chemistry indicated novel or otherwise unpredicted compounds act as pheromones. Several case studies demonstrate bioassay-guided fractionation as an approach to identification of pheromone in fish. The structural identification of pheromones will lead to use natural product as pheromones (Li et al., 2018).



Applications of pheromones aquaculture

- ✚ **Induction of Maturity and Reproduction:** Effective stimulation of sexual maturity with pheromones, could not only reduce the need for injections but may also improve the quality and, survival of resultant larvae and synchronization or timing of sexual maturity.
- ✚ **Delaying Precocious Maturation:** Early puberty is a problem for the aquaculture industry in many species due to the consequent allocation of energy reserves to the gonads rather than muscular growth. There may also be negative effects on appearance and flesh quality, thus reducing marketability. In aquaculture, cod tend to spawn at an earlier age than in the wild, presumably due to increased food intake and consequent deposition of lipid and protein reserves. If chemical communication can modulate the onset of puberty, then the high densities of fish in aquaculture are likely to exacerbate this problem.
- ✚ **Sex Determination:** In sequential hermaphroditic species, the proportion that changes sex may depend on social conditions. Sex pheromones could be used to sort males from females, and thereby reduce handling and associated stress. Pheromones could be used to attract those of the sex required in a similar way that invasive species may be trapped.
- ✚ **Welfare of animal:** Stress reduces food conversion efficiency and growth rates in fishes, so it is possible that monitoring cortisol in the water may be indirect way of assessing the level of stress in a tank of fish.
- ✚ **Using pheromones to facilitate trapping:** Trapping is done for simply remove organisms, and/or to collect animals. It is a low cost trap. Naturally, pheromone application should be considered together with the use of other attractant cues such as sound or light to get the best possible result. F prostaglandins from female could be considered for use in male trapping regimes. Similarly, male odours, androstenedione should be considered for use in to attract and remove females.
- ✚ **Using pheromones to disrupt movement and migration:** Migratory fish species such as the lampreys and chars appear to use pheromones to find spawning grounds from some distance. It is conceivable that pheromones could be used to divert migrations of invasive fishes to regions unsuitable for spawning or habitation.

✚ **Using pheromones to repel:** Many species of fish release alarm pheromones which have potential for keeping invasive fish away from areas of special concern such as optimal spawning habitat, places where ballast water is taken up. Repulsive odours such as alarm pheromones can easily be applied to prevent spread and will work in most situations.

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