



## Medicines in Fish Feed: A Double-Edged Tool in Modern Aquaculture

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Aquaculture has transformed from a traditional, small-scale activity into one of the most dynamic food-producing sectors in the world. With capture fisheries reaching their natural limits, farmed fish and shellfish now play a critical role in meeting the global demand for affordable animal protein. According to global estimates, more than half of the fish consumed by humans today originates from aquaculture systems. This rapid expansion, however, has come with a parallel rise in health-related challenges, particularly infectious diseases.

In intensive aquaculture systems, fish are often reared at high stocking densities, exposed to fluctuating water quality, and subjected to handling stress. These conditions can compromise immunity and create ideal environments for bacterial, fungal, viral, and parasitic infections. Disease outbreaks not only threaten animal welfare but can also result in severe economic losses for farmers. Against this backdrop, medicines incorporated into fish feed have emerged as one of the most widely used tools for disease control.

Medicated fish feed has undoubtedly contributed to improved survival, productivity, and economic stability in aquaculture. At the same time, growing scientific evidence has raised concerns about antimicrobial resistance, drug residues in edible tissues, and environmental contamination. As a result, the use of medicines in fish feed has become a subject of intense scientific, regulatory, and public debate. This article examines the issue in a structured and evidence-based manner, weighing the benefits against the risks and exploring the path forward for sustainable aquaculture.

### Understanding Medicated Fish Feed

Medicated fish feed refers to formulated aquaculture diets that contain approved therapeutic agents, such as antibiotics, antifungals, or antiparasitic compounds. These drugs are mixed into feed pellets at specific concentrations to ensure that fish receive the required dose during normal feeding activity. Oral administration through feed is generally preferred over injection or bath treatments, especially in large-scale farming, because it is practical, less labour-intensive, and causes minimal stress to fish.

In most aquaculture systems, medicated feed is prescribed for therapeutic purposes, meaning it is used to treat diagnosed disease outbreaks. In some cases, however, medicated feed has also been used prophylactically to prevent disease, particularly in regions where veterinary oversight is limited. The appropriateness of such preventive use remains a contentious issue within the scientific community.

Regulatory frameworks governing medicated feed vary widely across countries. While some nations enforce strict controls on drug approval, dosage, and withdrawal periods, others lack robust monitoring systems. International organizations such as the Food and

Agriculture Organization have repeatedly emphasized that medicated feed should only be used as part of an integrated fish health management strategy, rather than as a routine input (FAO, 2020).

### Scientific Basis for the Use of Medicines in Fish Feed

The use of medicines in aquaculture is rooted in well-established principles of veterinary science. When fish are affected by bacterial or fungal infections, timely treatment is essential to prevent mortality and limit pathogen spread. Oral delivery through feed allows for relatively uniform distribution of drugs within a population, provided that fish are actively feeding.

Several studies have demonstrated that appropriate use of medicated feed can significantly reduce mortality and improve recovery rates in cultured fish species (Done et al., 2015). Compared to immersion treatments, which release drugs directly into the water, oral administration reduces immediate drug exposure to the surrounding environment. This targeted delivery is often cited as a key advantage of medicated feed.

From an economic perspective, medicated feed can act as a safeguard against catastrophic losses. Disease outbreaks can wipe out entire crops, particularly in high-value species. For small- and medium-scale farmers, access to effective treatment options can mean the difference between financial survival and bankruptcy. Thus, the scientific rationale for medicated feed is closely linked to both animal welfare and livelihood security.

### Benefits of Medicated Feed in Aquaculture Systems

Medicated feed remains a cornerstone of modern aquatic animal health management. When applied under strict veterinary supervision, it offers a pragmatic solution to the unique challenges of treating large populations of aquatic animals.

#### Disease Control and Improved Survival

The primary justification for medicated feed is its efficacy in managing bacterial epizootics. In intensive aquaculture, where high stocking densities facilitate rapid pathogen transmission, the ability to deliver therapeutic agents quickly is critical.

- **Targeted Therapy:** Unlike bath treatments, which dilute medication in the water column and affect non-target organisms, medicated feed delivers the drug systemically via the gastrointestinal tract. This is particularly effective for systemic bacterial infections such as Vibriosis (caused by *Vibrio* spp.), Furunculosis (*Aeromonas salmonicida*), and Edwardsiellosis (*Edwardsiella ictaluri*) (Defoirdt et al., 2011).
- **Pathogen Load Reduction:** By treating the infection internally, medicated feed reduces the shedding of bacteria by infected fish. This lowers the overall pathogen load in the water, effectively "breaking the chain" of transmission to healthy tank-mates (Okocha et al., 2018).
- **Survival Rates:** Timely intervention with antibiotic impregnated feed has been shown to improve survival rates in outbreaks of *Streptococcus agalactiae* in tilapia and *Flavobacterium psychrophilum* in trout, preventing mortality events that could otherwise exceed 50-70% of the stock (Lulijwa et al., 2020).

#### Enhanced Animal Welfare

Minimizing stress is a key component of ethical aquaculture. The traditional alternative to oral therapy individual injection is highly stressful and labour-intensive.

- **Stress Reduction:** Handling fish for injection triggers a cortisol response that suppresses the immune system, potentially making them more susceptible to secondary infections or co-infections (Tort, 2011). Medicated feed allows for "hands-off" treatment, maintaining the integrity of the skin and mucus barrier the fish's first line of defence.
- **Reduced Handling Injuries:** Physical handling often leads to scale loss, epidermal damage, and osmoregulatory stress. By delivering medication through the diet, farmers avoid the physical trauma associated with netting and anaesthesia.
- **Behavioural Normalcy:** Effective treatment restores appetite and normal swimming behaviour more rapidly. As noted by Ashley (2007), the rapid alleviation of clinical

symptoms (e.g., lethargy, anorexia) is a fundamental aspect of welfare, and oral therapy achieves this with minimal disruption to the animal's environment.

### **Economic Stability and Productivity**

Disease is the single largest cause of economic loss in the global aquaculture industry, estimated to cost over \$6 billion annually (Stentiford et al., 2017).

- **Production Efficiency:** Chronic low-level infections increase the Feed Conversion Ratio (FCR), meaning fish eat more but grow less. By resolving these infections, medicated feed ensures that feed nutrients are used for growth rather than fighting disease, preserving the farmer's profit margins.
- **Market Consistency:** Uncontrolled outbreaks lead to "emergency harvests" of undersized fish or total crop failures. Therapeutic interventions stabilize production cycles, allowing farmers to meet harvest contracts and avoid market volatility.
- **Investment Security:** For small-scale farmers in developing nations, a crop failure can lead to insurmountable debt. The judicious use of medicated feed acts as an insurance policy, protecting the capital investment in seed, feed, and labor (Bondad-Reantaso et al., 2005).

### **Contribution to Food Security**

With the global population projected to reach 9.7 billion by 2050, aquaculture is increasingly relied upon to bridge the protein gap.

- **Protein Accessibility:** Fish provides nearly 20% of animal protein intake for over 3 billion people (FAO, 2022). Maintaining the health of farmed stocks is directly linked to the availability and affordability of this essential nutrient source.
- **Reducing Waste:** Disease-induced mortality is a form of food waste. By saving fish that would otherwise die, medicated feed improves the "seed-to-plate" efficiency of the food system.
- **Supporting Livelihoods:** In many regions of Asia and Africa, aquaculture supports rural livelihoods. Effective health management ensures that these farming systems remain viable and productive, contributing to local food resilience (Subasinghe et al., 2009).

### **Scientific and Environmental Concerns**

Despite its advantages, the use of medicated feed is associated with several well-documented risks.

#### **Antimicrobial Resistance**

One of the most pressing concerns is the development of antimicrobial resistance (AMR). When antibiotics are used frequently or at sub-therapeutic levels, bacteria can develop resistance mechanisms, rendering treatments ineffective over time. Uneaten medicated feed and fish excreta can introduce low concentrations of antibiotics into the aquatic environment, creating selective pressure on microbial communities (Cabello, 2006). The World Health Organization has identified antimicrobial resistance as one of the greatest threats to global health, warning that misuse of antimicrobials in food producing animals, including fish, can contribute to the spread of resistant bacteria (WHO, 2017).

#### **Drug Residues and Food Safety**

Another major concern is the presence of drug residues in fish tissues. If withdrawal periods are not strictly observed, residues may persist in edible flesh, posing potential risks to consumers. Residue violations can also lead to rejection of aquaculture products in domestic and international markets, damaging the reputation of entire sectors (Done et al., 2015).

#### **Environmental Impacts**

Uneaten medicated feed often sinks to the bottom of ponds, cages, or tanks, exposing sediments and benthic organisms to pharmaceuticals. Over time, this can alter microbial communities, affect nutrient cycling, and reduce environmental quality. Studies have shown that aquaculture sediments can act as reservoirs of antibiotic residues and resistant bacteria (Sapkota et al., 2008).

## Public Health and Socio-Economic Implications

The implications of medicated feed extend far beyond fish farms. Consumers are increasingly concerned about the safety and sustainability of their food. Media coverage of antibiotic use in animal agriculture has heightened public awareness and scrutiny of aquaculture practices. From a public health perspective, the potential transfer of resistant bacteria or resistance genes from aquatic environments to humans is a significant concern. Although direct transmission pathways are complex and not fully understood, the precautionary principle supports minimizing unnecessary antimicrobial use. Economically, countries that fail to regulate medicated feed risk losing access to export markets with strict residue standards. Conversely, producers who adopt responsible practices may gain a competitive advantage by meeting certification and eco-labelling requirements.

## Regulatory Frameworks and Scientific Consensus

There is broad scientific consensus that medicated feed should not be eliminated entirely, but its use must be strictly regulated and scientifically justified. International guidelines emphasize:

- Use of medicines only for diagnosed diseases
- Veterinary oversight and prescription
- Adherence to recommended dosages and withdrawal periods
- Record-keeping and traceability

The FAO and other international bodies advocate for a One Health approach, recognizing the interconnectedness of human, animal, and environmental health (FAO, 2020).

## Alternatives and Complementary Strategies

While medicated feed is a critical emergency brake, it should not be the engine that drives aquaculture. A sustainable future relies on Integrated Health Management (IHM); a holistic approach where prevention is prioritized over cure. As illustrated in the *Aquaculture Disease Management* framework, the industry is moving toward a multi-faceted defence system that reduces reliance on chemical interventions.

### Vaccination

Vaccination is arguably the greatest success story in modern aquaculture. It represents a shift from treating the sick to protecting the healthy.

- **Mechanism:** Vaccines introduce a benign form of a pathogen (or its DNA) to the fish, training its immune system to recognize and destroy the real threat upon future exposure. The diagram highlights various types, including "DNA vaccines, synthetic peptides, killed vaccines, and live attenuated vaccines".
- **Impact:** The salmon industry in Norway is a prime example, following the introduction of effective vaccines against *Vibrio* and *Furunculosis* in the late 1980s, antibiotic use dropped by 99% even as production sky rocketed (Midtlyng et al., 2016).
- **Delivery:** While injection remains common, innovation is focusing on oral vaccines (delivered via feed) and immersion vaccines, which reduce handling stress.

### Probiotics and Immunostimulants

This strategy focuses on "fortifying the fortress" rather than fighting the enemy directly. It leverages "Probiotics, Pre-Biotics, and Botanicals" to enhance the fish's natural defenses.

- **Probiotics:** These are live, beneficial bacteria (e.g., *Bacillus*, *Lactobacillus*) added to feed or water. They colonize the fish's gut, outcompeting pathogenic bacteria for space and nutrients—a concept known as competitive exclusion (Newaj-Fyzul et al., 2014).
- **Immunostimulants:** Substances like beta-glucans (from yeast) or specific herbal extracts (botanicals) can "wake up" the fish's innate immune system, making white blood cells more aggressive against invaders.
- **Botanicals:** The diagram notes the use of "Botanicals". Essential oils from plants like oregano, garlic, and thyme have shown natural antimicrobial properties, offering a "green" alternative to synthetic antibiotics.

### Improved Farm Management

The most effective medicine is a clean home. As the "Pond Management Cultural Practices" section of the diagram suggests, manipulating the environment is the first line of defense.

- **Stocking Density:** Overcrowding increases stress and pathogen transmission. Optimizing density ensures fish have enough space to swim and breathe, reducing cortisol levels and susceptibility to disease.
- **Water Quality:** Maintaining optimal levels of dissolved oxygen, pH, and ammonia is crucial. Poor water quality damages fish gills and suppresses the immune system, making them easy targets for bacteria.
- **Biosecurity Methods:** The diagram emphasizes "Biosecurity Methods (use of disease-free animals)". This includes screening fry (baby fish) for specific pathogens before stocking them (Specific Pathogen Free or SPF stocks) and disinfecting equipment to prevent introducing new diseases to the farm.

### Chemical Control

While the goal is to reduce chemicals, the diagram acknowledges "Chemical Control (use of biocides)" as a component of disease management.

- **Role:** These are typically disinfectants (like iodine or hydrogen peroxide) used to clean equipment, footbaths, and sometimes water, rather than treating the fish internally. They act as a firewall to stop pathogens from entering or persisting in the facility.

### Future Outlook: Toward Responsible and Sustainable Use

The future of aquaculture health management lies in integration rather than dependence. Medicines will continue to play a role, but as part of a broader strategy that prioritizes prevention, monitoring, and innovation. Advances in diagnostics, precision feeding, and selective breeding for disease resistance offer new opportunities to reduce drug use without compromising productivity. Policy-makers, researchers, farmers, and consumers all have a role to play. Transparent communication, evidence-based regulation, and capacity building at the farm level are essential for building trust and ensuring long-term sustainability.

### Conclusion: Balancing Benefit and Responsibility

Medicines in fish feed represent a powerful but sensitive tool in modern aquaculture. Scientifically, they offer clear benefits in disease control, animal welfare, and food security. At the same time, their misuse carries real risks to public health, the environment, and the credibility of the aquaculture industry. The question is not whether medicated feed is a boon or a bane, but how responsibly it is used. By grounding decisions in science, strengthening regulation, and investing in preventive strategies, aquaculture can harness the benefits of medicated feed while minimizing its risks. In doing so, the sector can continue to grow sustainably and retain public trust in farmed fish as a safe and healthy food source.

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