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A Novel *Artemia* Dispenser for Larval Fish Culture

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Abstract

Artemia (brine shrimp) are frequently used as a food source during the rearing of juvenile fish species. However, manually dispensing *Artemia* is labor intensive and inconsistent, while fully automated *Artemia* dispensing systems can be cost prohibitive. This paper describes the design, construction, and evaluation of a low-cost and easily-fabricated *Artemia* nauplii dispenser used during the early rearing of larval fish in a recirculating aquaculture system. The gravity-fed drip dispenser was constructed from polyvinyl chloride components and was designed to deliver a consistent supply of *Artemia* for six hours. During actual operation, the feeder performance was greatly influenced by the hatched *Artemia* slurry viscosity, clogging from unhatched cysts, and flow rate control mechanisms. Instead of the six-hour goal, feeding only occurred for three hours under optimal conditions. Despite these limitations, using this feeder proved beneficial by extending *Artemia* availability to larval fish for a longer period of time than manual feeding. The feeder integrated well with existing hatchery infrastructure. Modifications to improve feeder reliability and accuracy included replacing a push-lock fitting with a series of vinyl tubing segments, adding a dripline irrigation valve, using a salt buffer prior to adding *Artemia* to lessen slurry viscosity, and thorough removal of unhatched cysts and eggshells to prevent clogging.

Keywords

Artemia, Larval Fish, Dispenser, Recirculating Aquaculture System

1. Introduction

In aquaculture, larval fish may not readily accept artificial diets during initial feeding, resulting in poor survival. *Artemia* spp. (brine shrimp) are often used as a substitute for natural forage [1]. *Artemia* are small crustaceans that inhabit hypersaline environments worldwide, with approximately 90% of commercial supply sourced from the Great Salt Lake in Utah, USA [1].

Artemia produce embryos (cysts) which go dormant in unfavorable hatching conditions and can withstand extreme environments for long periods of time [2]. The 200-to-300-micron cysts can be dehydrated, packaged, and stored for several years. When provided optimal hatching conditions, cysts hatch into free swimming juveniles (nauplii) in as little as 24 hours. The cysts are graded by hatching success, with one gram of premium cysts yielding approximately 250,000 nauplii. Under ideal conditions, *Artemia* live up to three months, and may grow to 10 mm in length [3]. In aquaculture, it is the nauplii, approximately 0.4 mm in length after the first 24 - 36 hours, that are typically used because of the gape limitations of larval fish [4].

Artemia stocking density (nauplii/L) is dependent on the species and developmental stage of fish [5]. To maintain desired stocking densities, techniques range from manual dispensing to fully automated delivery systems [6]. Incorporating automation to feed delivery improves fish feeding consistency, while at the same time reducing staff labor [7]. However, fully automated systems can be expensive and require extensive retrofits to existing infrastructure [8].

This paper describes the design and function of an *Artemia* dispenser developed to streamline feeding in recirculating aquaculture systems for rearing larval fish. The goal of the dispenser design was to reliably maintain appropriate nauplii densities for approximately six hours past filling. The six-hour objective was chosen to provide a consistent supply of *Artemia* for a total of twelve hours per day, while limiting the need to refill the dispenser within an eight-hour workday.

2. Design

2.1. Main Components

Figure 1. The main body and end cap of a novel *Artemia* feeder.

The delivery system was comprised of four components: 1) main dispenser body, 2) air delivery system, 3) sight glass, and 4) tank bracket system. The main body of the dispenser was constructed from 152 mm diameter Standard Dimension Ratio 35 (SDR 35) Polyvinyl Chloride (PVC) sewer pipe cut to 413 mm long. A 152 mm SDR 35 PVC cap was glued onto the 413 mm pipe using clear PVC Primer and Regular Body Medium Set PVC glue (**Figure 1**). The union of the cap and cut length of pipe produced a capacity of 5.5 liters with 108 mm of free board to prevent spilling.

2.2. Inner Air Delivery

A 15.9 mm hole was drilled into the top of the dispenser to install fittings for the internal air delivery system. From inside the dispenser, the threaded end of a 9.5 mm-barbed × 9.5 mm-male pipe thread (MPT) polyethylene 90-degree elbow was inserted through the hole. Inside the dispenser, a 330 mm length of 9.5 mm inner diameter (I.D.) clear vinyl tubing connected the barbed end of the MPT elbow to a 52 mm aquarium air stone (**Figure 2**).

Figure 2. The inner air delivery system for a novel *Artemia* feeder.

2.3. External Air Delivery

On the outside, a 9.5 mm barbed × 9.5 mm -female pipe thread (FPT) polyethylene 90-degree elbow was threaded onto the exposed male pipe threads to secure the connection (**Figure 3**). A 9.5 mm I.D. clear vinyl tubing connected the barbed end of the FPT elbow to a common airline supplying all *Artemia* dispensers. A constant air supply provided oxygen and ensured a homogenous concentration of *Artemia* throughout the feeding cycle. The common airline was made from 12.7 mm clear vinyl tubing (Sioux Chief, Kansas City, Missouri, USA) and branched to each *Artemia* dispenser using 12.7 mm × 12.7 mm × 9.5 mm barbed tees (**Figure 4**). Air was supplied to the common airline by an Aqua Miracle AP160 diaphragm air pump (Amazon, Seattle, Washington, USA).

Figure 3. The outside air delivery system for a novel *Artemia* feeder.

Figure 4. *Artemia* feeders connected by a common airline (note orange arrows).

2.4. *Artemia* Delivery

A 12 mm hole was drilled in the center of the glued cap at the bottom of the feeder, and an 8 mm Uniseal (The Uniseal Warehouse, St. Cloud, Florida, USA) was inserted into the hole. A 100 mm length of 9.5 mm outside diameter (O.D.) PEX tubing was then pushed through the Uniseal (**Figure 5**). A 9.5 mm push-to-connect plastic valve (Watts AquaLock Push-to-Connect Plastic Valve, Watts Water Technologies, North Andover, Massachusetts, USA) was attached to the protruding end of the PEX tubing. This valve, positioned at the lowest point of the dispenser, allowed for modulation of the *Artemia* slurry dispersion rate.

At the bottom (cap end) of the feeder a 14.7 mm hole was drilled approximately 25 mm from the base of the dispenser. Threads were cut into the drilled hole using a 9.525 mm, 18 NPT tap, and a 9.5 mm barbed × 9.5 mm MPT 90-degree elbow was threaded into the tapped hole. A 380 mm section of 9.5 mm I.D. tubing was affixed to the barbed end of the MPT elbow and oriented to the top of the dispenser. Near the top of the dispenser, two 4.8 mm holes were drilled 19 mm from the rim, and a cable tie was used to secure open end of the tubing. Marks were added to the tubing in 0.5 liter increments, from 1.0 liter to 5.5 liters, to reflect the volume of *Artemia* slurry within the dispenser (**Figure 6**).

Figure 5. Uniseal and PEX tubing at the bottom end of a novel *Artemia* feeder.

Figure 6. View tube with graduation marks on the outside of a novel *Artemia* feeder.

2.5. Feeder Mounting

To position the *Artemia* dispenser above the fish culture units, a stainless-steel Arvo-Tec TD 2000 Hinged Hanger was used (Arvo-Tec Oy, Huutokoski, Finland). The hanger has two bands originally designed to secure the top of an Arvo-Tec TD 2000 feeder. These two bands closely matched the diameter of the *Artemia* dispenser and were easily adapted to fit with a tension hold when bolted together (**Figure 7**). To mount the hanger to the tank wall, a piece of 4.8 mm × 51 mm aluminum angle, approximately 140 mm in length, was attached to the bottom of the hanger using two M6 × 1.0 mm × 25 mm stainless steel bolts, lock washers, and hex nuts. This modification allowed the dispenser to be easily mounted to the tank wall by sliding it over the tank lip (**Figure 8**).

Figure 7. Novel *Artemia* feeder connected to an Arvotech TD 2000 mounting assembly.

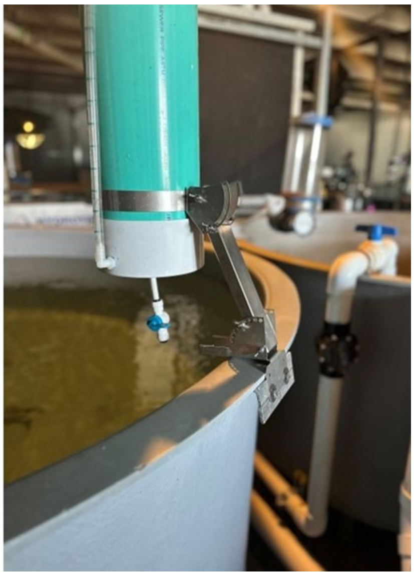

Figure 8. Novel *Artemia* feeder dispenser mounted on the lip of a larval fish rearing tank.

2.6. Cost

The cost to construct the entire feeder was approximately $20 USD. In contrast, the cost of commercially available *Artemia* dispensers for aquaculture use range from $300 to over $1,500 USD.

3. Evaluation

The feeder was evaluated during the initial rearing of larval muskellunge (*Esox masquinongy*) in a recirculating aquaculture system. The feeder was filled with 91,000 nauplii/L. Dispensing rates were set at 46 ml/min, which was the lowest rate that could be used without clogging occurring. At 46 ml/min, the dispenser effectively dispensed *Artemia* nauplii, but failed to provide the required precision and dispensing was still too inconsistent. In an attempt to fix these problems, two retrofits were made.

Retrofits

The first retrofit replaced the push-lock fitting with a series of vinyl tubing segments, each progressively reducing in diameter to decrease the flow rate (**Figure 9**). The protruding PEX tubing fit securely into 9.5 mm I.D. clear vinyl tubing, followed by a series of step-down connections: 6.4 mm I.D., 4.8 mm I.D., and a 2.38 mm fuel line. At each transition, the outer diameter of the smaller tubing allowed for a secure, press-fit connection into the inner diameter of the next larger segment. This retrofit improved reliability, but accuracy was still problematic.

Figure 9. Retrofit of an *Artemia* feeder showing the decreasing diameters of vinyl tubing.

The second retrofit retained the 9.5 mm, 6.4 mm, and 4.8 mm I.D. segments of tubing, but added a dripline irrigation valve (Rain Bird, Azusa, California, USA) onto the 4.8 mm I.D. segment (**Figure 10**). The addition of the drip line valve improved accuracy and reliability to an acceptable level. To standardize starting volumes, each dispenser was filled with the correct *Artemia* concentration and a 30 ppt salt buffer added to the 5.5 liter mark of each feeder. A standard starting point in each dispenser allowed hatchery staff to monitor and adjust dosing rates throughout the day. Adding this salt buffer prior to adding *Artemia* also decreased slurry viscosity, which greatly improved *Artemia* dispensing by the feeder.

During actual operation, the feeders produced mixed results. It was critical to thoroughly remove unhatched cysts and eggshells to prevent clogging in the narrow diameter drip lines. Under ideal conditions, feeders extended feeding events by three hours, short of the six-hour goal. This resulted in more frequent-than-desired refills to maintain target *Artemia* stocking densities.

Figure 10. Additional retrofit of a novel *Artemia* feeder showing the addition of a drip line irrigation valve to modulate dispenser flow.

4. Conclusion

In conclusion, the *Artemia* dispenser design functioned effectively, though not exactly as intended. The dispenser was relatively easy to construct using inexpensive and widely available materials. It also integrated well with existing hatchery infrastructure. This design did not achieve the goal of delivering *Artemia* over 6 hours. However, increasing the number of daily refills was a simple solution that still required considerably less labor than manual feeding.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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