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Optimization of Hatchery Techniques to Enhance Larval Survival and Business Feasibility of Guppy (*Poecilia reticulata*)

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ABSTRACT

Optimizing hatchery techniques for guppy (*Poecilia reticulata*) production is essential for improving reproductive efficiency and economic viability in small-scale ornamental aquaculture. This study evaluated the effectiveness of a simplified spawning system using sterilized aquaria (40×60×40 cm) with aeration and aquatic vegetation to create a semi-natural environment. Broodstock selection based on gonadal maturity and a male-to-female ratio of 2:4 resulted in high spawning success, with courtship behavior observed by day three. A staged feeding strategy—infusoria and egg yolk (days 1–3), Artemia nauplii (days 4–10), and Tubifex (days 11–21)—supported consistent larval growth from 0.5 cm to 1.6 cm over three weeks. Larval survival reached 91.1%, with 162 of 168 fry surviving by day 21. Stable water quality parameters (24–26°C, 7.6–7.9 mg/L dissolved oxygen, pH 6.7–7.1) were maintained through regular siphoning and water renewal. Economic analysis indicated system feasibility, with a production cost of IDR 1,369,250, revenue of IDR 1,620,000, and net profit of IDR 250,750. The benefit-cost ratio (R/C) was 1.18, the break-even point was achieved at 136.93 fry, and the payback period was 17.7 months. These findings highlight the biological and financial viability of low-cost guppy hatchery systems suitable for rural aquaculture settings. Future research should focus on scaling potential, feed alternatives, and digital monitoring to improve system sustainability and profitability.

INTRODUCTION

The guppy fish (*Poecilia reticulata*) is known for its vibrant color, ease of breeding, and adaptability, making it one of the most popular freshwater ornamental species. Guppies show rapid adaptation to new environments, as evidenced by experimental populations transplanted from high-predation environments to low-predation environments. Invasive guppy populations in the Hawaiian Islands have shown significant population structure and local adaptation, suggesting that natural selection played an important role in their evolutionary success in new environments (Rosenthal et al., 2021). Female guppies prefer males with brighter colors, which affects reproductive strategies such as fertilization time. Females tend to fertilize eggs early when mating with attractive males, supporting the exchange hypothesis that females seek to optimize offspring quality (Sato et al., 2021). Male guppies also display preferences based on female behavior, such as swimming activity, which may indicate female qualities or reproductive states (Bierbach et al., 2021).

The global demand for guppy fish, a popular ornamental species, has significantly increased. The ornamental fish trade is a significant pathway for introducing non-indigenous species into the aquatic environment. The guppy (*Poecilia reticulata*) is one of the three most frequently imported aquatic ornamental species globally, along with the neon tetra and tiger's spines. This highlights its popularity and high demand in the ornamental fish market (Atalah et al., 2022). The ornamental fish market has grown significantly in Asia, Europe, and North America. The growing interest in aquariums supports this expansion as a hobby, and the aesthetic appeal of ornamental fish such as guppies (Tarihoran et al., 2023). Aquaculture plays a crucial role in meeting the increasing demand for ornamental fish. The sector has grown rapidly, with aquaculture production surpassing capture fisheries in many regions. This growth is critical to maintaining the supply of ornamental fish such as guppy fish, which are extensively bred in aquaculture facilities (Mair et al., 2023).

Hatching performance, especially larval survival, is important to aquaculture production success and stock quality. Various factors affect larval survival, including feeding practices, environmental conditions, genetic diversity, and disease management (Buchalla et al., 2023; Kourkouta et al., 2022; Reyes et al., 2022). Delayed feeding of short-nosed sturgeon larvae affects growth and survival, with a significant decrease in survival rates observed when feeding is delayed for more than 10 days after yolk intake. This highlights the importance of timely feeding to ensure a high survival rate (Hardy et al., 2021). The timing and size of hatchery release are critical for juvenile to adult survival in salmon species. Previous releases of Chinook salmon and subsequent releases of coho salmon were associated with higher survival rates, emphasizing the need for strategic release practices (James et al., 2023).

Indonesia, which is recognized as a tropical biodiversity hotspot, has significant potential to develop guppy hatcheries due to its rich water resources and favorable climate. Indonesia's tropical climate and rich biodiversity provide an ideal environment for aquaculture cultivation, including guppy hatcheries. Ample water resources and favorable temperatures support the growth and reproduction of guppy fish, making them a promising location for developing nesting grounds (Tarihoran et al., 2023). The global aquaculture industry is growing rapidly, with Indonesia being a significant player. The country's aquaculture sector is expected to grow, driven by the increasing demand for ornamental fish and other aquatic products (Mair et al., 2023).

Despite extensive research on the reproductive properties of guppy fish, there are still significant gaps in empirical studies focusing on optimizing hatching protocols under controlled conditions. This gap is particularly evident when considering the reproductive complexity of guppies, which involves factors such as sexual competition, genetic determinants, and environmental influences (Borges et al., 2022). The existing literature provides insight into various aspects of guppy biology, but comprehensive studies translating these findings into practical hatchery applications are limited (Charlesworth et al., 2020; Daniel & Williamson, 2020; Patil et al., 2020).

The relationship between hatching practices and economic performance in guppy larval production remains unexplored, especially in terms of cost efficiency, revenue-to-cost ratio

(R/C), and break-even point (BEP) (Cheatham et al., 2023). Although there has been extensive research on aquaculture practices and their economic implications on other species, such as tilapia, catfish, and red snapper, specific studies on guppy production are still lacking (Chávez-Villalba et al., 2022; Lobillo-Eguíbar et al., 2020). The gaps in this study highlight the need for targeted studies to understand how hatching practices can be optimized for economic performance in guppy production (Marshak & Link, 2021; Pincinato, 2021).

Cultivating ornamental fish, especially the guppy (*Poecilia reticulata*), has high economic potential in line with the increasing global market demand. However, unstable seed productivity and low larval survival rates are significant challenges in guppy hatchery systems, especially at the level of small and medium-sized cultivators. Meanwhile, most previous research has only focused on biological aspects, such as growth and environmental adaptation, without considering aspects of production cost efficiency and business feasibility. The success of seeding is measured not only from biological parameters alone but also from the financial aspects that determine the sustainability of the business. Therefore, an integrative and applicative approach is needed to optimize guppy hatchery techniques that are technically effective and economically efficient.

This research offers novelty by integrating hatchery techniques—including broodstock selection, spawning ratio, feed management, and water quality—with the analysis of larval growth, survival rate, and business feasibility based on the calculation of R/C ratio, Break Even Point (BEP), and profit margin. The resulting hatchery model not only provides measurable technical guidance but also emphasizes the profitability of the guppy hatchery business on a small scale. The main objective of this study is to evaluate hatchery techniques that can improve larval survival systematically and, at the same time, be financially profitable so that it can be a real solution in the development of sustainable and community-based ornamental fish aquaculture.

METHODS

Experimental Design

This study employed a field-based experimental approach with a quantitative descriptive design to evaluate the effects of optimized hatchery techniques on larval survival and economic feasibility in the seed production of guppy (*Poecilia reticulata*). The experiment was conducted from July to August 2024 at the Lingsar Fish Seed Center (BBI) in West Lombok, West Nusa Tenggara, Indonesia. This facility represents typical daily small-scale, semi-intensive hatchery operations in tropical aquaculture systems and is equipped with water management infrastructure for controlled experimental conditions.

A single broodstock ratio of 2:4 (male:female) was used to assess its impact on spawning success and larval viability. Environmental conditions such as temperature, dissolved oxygen, and pH were monitored and maintained within optimal ranges. A feeding regime was also implemented, utilizing natural feed types tailored to larval developmental stages to ensure sufficient nutrient availability and feed conversion efficiency.

A total of 24 broodstock fish (8 males and 16 females) were distributed evenly into four spawning tanks (40 × 60 × 40 cm). Each setup was replicated twice to ensure data reliability. Observations continued over a 21-day rearing period, during which biological parameters (growth and survival) and economic metrics (cost and profitability) were evaluated.

Broodstock Selection and Spawning

Broodstock was selected based on morphometric and behavioral health and reproductive readiness indicators. Males were chosen for their bright coloration and streamlined body shape, while females exhibited larger body sizes, distended abdomens, and lacked a gonopodium. All broodstock were at least three months old and measured between 3.5 and 4.5 cm long.

Spawning aquaria were sanitized using potassium permanganate ($KMnO_4$), air-dried, and filled with dechlorinated freshwater aged for 24 hours. Aeration was applied to maintain oxygenation and aquatic vegetation such as Hydrilla was added to simulate natural shelter. After a 15-minute acclimatization period, the broodstock was introduced based on the assigned ratio. Gravid females showing dark abdominal spots were subsequently transferred to separate birthing tanks to prevent cannibalism and environmental stress during parturition.

Larval Rearing

Following gradual acclimatization, newly hatched larvae were carefully transferred to designated rearing tanks using soft pipettes or plastic spoons. Stocking densities were kept consistent across all units. Feeding was scheduled according to larval stage: infusoria and boiled egg yolk (days 1–3), Artemia nauplii (days 4–10), and cleaned Tubifex worms (days 11–21). This feeding sequence ensured appropriate feed size and nutritional composition for each developmental phase.

Larvae were fed ad libitum twice daily at 8 am and 4 pm. Daily siphoning was conducted to remove organic residues to maintain water quality, and 30% water exchanges were performed twice weekly. Rearing was conducted indoors to limit exposure to direct sunlight and potential predators, creating a stable and low-stress environment conducive to optimal growth and survival.

These procedures were directly aligned with the biological outcomes and economic evaluations presented in the results, supporting the integrated analysis of hatchery technique efficiency and financial viability.

Data Collection

Data collection in this study focuses on two main groups of parameters, namely biological and environmental parameters that affect guppy fish's hatchery and larval maintenance results (*Poecilia reticulata*). The biological parameters observed consisted of the survival rate (SR) and the absolute length growth of the larvae. Observations were made periodically during the larval rearing period, namely on days 0, 7, 14, and 21. Survival is calculated using the formula:

$$\mathrm{SR}\ (\%) = \left(\frac{\mathrm{Nt}}{\mathrm{N0}}\right) \mathrm{x}\ 100$$

SR is the survival rate, Nt is the number of fish at the end of the study, and N0 is the number of fish at the beginning of the study. Meanwhile, the absolute growth length is calculated based on the difference between the final length (Lt) and the initial length of the larvae (L0), with the formula:

$$\mathrm{L} = \mathrm{Lt} - \mathrm{L0}$$

Body length measurements were randomly performed on 10 larvae from each treatment aquarium using digital calipers (0.01 mm accuracy). The measurement results are averaged to obtain a representative value of growth each week.

The water quality parameters collected included water temperature (°C), dissolved oxygen (DO, mg/L), and pH. The temperature is measured with a digital thermometer by dipping it in aquarium water and recording the results once it has stabilized. DO is measured using a portable DO meter, while a digital pH meter determines pH. Measurements are taken at the beginning and end of maintenance and randomly during the process to ensure the environment remains stable within the optimal range of larval growth.

Economic Evaluation

An economic analysis was carried out based on a simple financial evaluation method applied in freshwater fish hatchery activities to assess the business feasibility of the tested hatchery techniques. The cost components consist of fixed and variable costs, such as the purchase of aquariums, aerators, feed, electrical energy, and labor.

The formula calculates the total cost of production:

$$\mathrm{TC} = \mathrm{FC} + \mathrm{VC}$$

TC is the total cost, FC is a fixed cost, and VC is a variable cost. Revenue is calculated based on production output (number of live larvae) multiplied by the selling price of guppy seeds per head in the local market. Business profits are obtained from the difference between revenue and total production costs:

$$\pi = \mathrm{R} - \mathrm{TC}$$

Next, the revenue-to-cost ratio (R/C Ratio) is calculated:

$$\mathrm{R/C} = \frac{\mathrm{R}}{\mathrm{TC}}$$

R/C > 1 indicates that the hatchery business is financially viable. In addition, Break Even Points (BEP) are also determined in two forms, namely:

$$\text{BEP unit} = \frac{\mathrm{TC}}{\text{Selling price per unit}}$$

$$\text{BEP price} = \frac{\mathrm{TC}}{\text{Production amount}}$$

Finally, the Payback Period (PP) is estimated, which is the time needed to recover the total initial investment from the net profit earned per production period:

$$\mathrm{PP} = \frac{\text{Total investment}}{\text{Net profit}}$$

All financial data were gathered through direct observation and market verification within the West Lombok region, ensuring contextual accuracy. These economic metrics were essential for linking hatchery practices to financial outcomes, thereby addressing a key research gap in guppy aquaculture economics.

Data Analysis

All biological and economic data are analyzed using descriptive statistics, including mean, and presented as tables and graphs to facilitate visual interpretation. Comparisons between treatments were analyzed based on trends in survival rate, larval growth, and business feasibility indicators such as profit and revenue-to-cost ratio. Water quality data were evaluated concerning the optimal range recommended in the literature for guppy hatchery performance.

RESULTS

Measured weekly, larval length increased from an initial mean of 0.5 cm to 0.7 cm (week 1), 1.2 cm (week 2), and 1.6 cm (week 3), demonstrating a consistent growth trajectory (Figure 1). This growth pattern corresponds with the nutrient-rich diet and stable water parameters maintained during the rearing period.

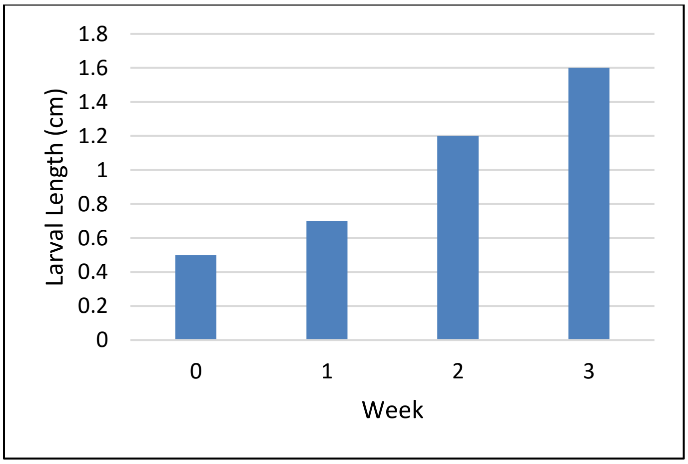

Figure 1. Larval Length

Consistent water quality during the study was critical for ensuring larval health (Table 1).

Table 1. Water Quality Parameters During Research

Parameters	Unit	Observation Result		Optimal Range
		Broodstock Aquarium	**Larval Aquarium**	
Temperature	^{0}C	24-26	24-26	25-33 (Habibi, 2022)
DO	mg/L	7.6-7.9	7.6-7.9	>3 (Habibi, 2022)
pH	-	6.7-7.0	6.7-7.1	6.5-7.5 (Habmarani et al., 2023)

DISCUSSION

Effectiveness of Spawning Setup and Broodstock Selection

Successfully optimizing hatchery techniques in guppy fish (*Poecilia reticulata*) depends critically on the initial stages of spawning preparation and broodstock selection. In this study, sterilized aquaria (40×60×40 cm) with aeration systems and aquatic vegetation provided a stable, semi-natural microenvironment that minimized stress and maximized reproductive performance. The sanitation protocol, which included $KMnO_4$ treatment and a 24-hour water conditioning period, is in line with best practices in ornamental aquaculture (Dadiono et al., 2023; Kembaren, 2022), effectively reducing microbial load and residual chlorine.

The broodstock selection based on morphological and reproductive maturity characteristics resulted in a high spawning success. The males (3.5 cm) and females (4.7 cm) used were within the optimal gonadal maturity range (3–4 months of age), with visual cues such as gravid spots indicating successful insemination (Syarif et al., 2021). The 2:4 male-to-female ratio provided sufficient male presence for fertilization while minimizing aggressive interactions. Behavioral observations of courtship initiation on day three post-introduction support the effectiveness of this configuration. These findings validate the importance of broodstock management as a determinant of reproductive efficiency in live-bearing ornamental fish.

Nutritional Strategy and Larval Growth Performance

Larval nutrition played a central role in ensuring uniform growth and high survival. The staggered feeding protocol, transitioning from infusoria and egg yolk (days 1–3) to Artemia nauplii (days 4–10) and Tubifex (days 11–21), ensured age-appropriate feed particle size and digestibility. The ad libitum feeding regime, applied twice daily, aligns with findings by Situmorang et al. (2023), who demonstrated that unrestricted feeding promotes larval satiation, enhances protein assimilation, and minimizes competition.

Usman et al. (2022) emphasized that larval growth is influenced by both feed quality and environmental conditions, which were optimized in this study. The strong linear growth suggests that the nutritional protocol supported maintenance metabolism and promoted tissue accretion, essential for healthy juvenile development.

Larval Survival Rate as a Benchmark of Hatchery Success

Survival rate (SR) is a vital indicator of hatchery success, reflecting the combined influence of environmental stability, nutritional adequacy, and husbandry practices. The study recorded an SR of 91.1%, with 162 of 168 larvae surviving through day 21. This figure far exceeds small-scale aquaculture's acceptable 70% threshold (Syarif et al., 2021). The high SR demonstrates the synergy between good broodstock health, appropriate feed strategy, and optimal water management. These results are consistent with prior findings in ornamental fish hatcheries, where water quality and early feeding strategies significantly influence larval viability (Hardy et al., 2021).

Water Quality Stability as a Supporting Factor

The temperature was maintained between 24–26°C, aligning with optimal ranges for guppy development (23–27°C), as Kusumaraga et al. (2021) reported. Dissolved oxygen levels remained between 7.6–7.9 mg/L, well above the minimum requirement of 5 mg/L (Habibi, 2022), indicating an oxygen-rich environment that supports metabolic activity and waste detoxification.

pH levels ranged from 6.7 to 7.1, which, although slightly acidic at the lower end, remained within the tolerable limits for guppy physiology (Habmarani et al., 2023). Fluctuations in pH can influence ammonia toxicity and microbial balance; hence, the regular siphoning and 30% water renewal twice weekly proved effective in stabilizing conditions. Maintaining these parameters underscores the necessity of active water management in enhancing larval resilience and survival.

Economic Feasibility of the Optimized Hatchery System

Integrating biological performance with economic analysis provides a holistic evaluation of hatchery optimization. Total production cost was IDR 1,369,250, with gross revenue of IDR 1,620,000, yielding a net profit of IDR 250,750. The resulting R/C ratio of 1.18 indicates profitability, as values >1 reflect financial viability (Zuhri et al., 2021). The break-even point (BEP) was achieved at 136.93 fry sold at IDR 8,452 per unit, confirming that the system surpassed operational costs within a single production cycle.

A payback period (PP) of 17.7 months suggests a feasible return on investment for small-scale producers. These findings are particularly relevant in rural aquaculture entrepreneurship, where low-cost, high-efficiency systems are critical. The demonstrated profitability, high survival, and growth suggest that this hatchery model can be a replicable prototype for community-based ornamental fish farming.

While the economic performance metrics reported here, such as the R/C ratio and BEP, are promising, they also help address a broader research gap. Cheatham et al. (2023) noted that the relationship between hatchery practices and economic outcomes in guppy production remains underexplored. Unlike well-documented systems in species such as tilapia, catfish, and red snapper (Chávez-Villalba et al., 2022; Lobillo-Eguíbar et al., 2020), guppy hatcheries have received limited empirical economic evaluation. This study offers novel insight into how technical hatchery practices can be optimized for biological performance and economic efficiency, particularly in smallholder contexts where resource limitations constrain profitability. Furthermore, this research provides actionable benchmarks for guppy hatchery operators by quantifying investment recovery through PP and identifying economically viable thresholds via BEP.

Broader Implications and Future Directions

The results of this study substantiate the viability of small-scale guppy hatcheries employing simple yet optimized techniques. The synchronization of biological and economic success highlights the importance of integrated aquaculture models that address technical performance and financial outcomes. This approach suits developing regions with limited access to advanced hatchery infrastructure.

Future research should explore the potential for scalability, genetic quality control of broodstock, and comparative trials involving artificial feeds to further refine the system's cost-effectiveness. Additionally, incorporating digital monitoring tools for real-time water quality assessment could further enhance operational efficiency. Overall, this study contributes to the growing knowledge supporting sustainable, inclusive, and economically viable ornamental aquaculture.

CONCLUSION

This study demonstrates that optimized hatchery protocols—encompassing broodstock selection, environmental management, and stage-specific nutritional strategies—significantly enhance reproductive performance, larval growth, and survival in guppy (*Poecilia reticulata*) aquaculture. A high survival rate (91.1%), consistent linear growth trajectory, and stable water quality parameters underscore the biological robustness of the system. At the same time, economic analysis confirms its feasibility with a favorable R/C ratio of 1.18, a BEP of 136.93 fry, and a payback period of 17.7 months. These findings validate the integration of biological optimization with economic efficiency, offering a replicable and scalable model for community-based ornamental fish hatcheries in resource-limited settings. The study provides novel empirical benchmarks for guppy hatchery operations and paves the way for future research on genetic refinement, cost-efficiency through feed innovations, and digital water quality monitoring to support sustainable small-scale aquaculture further.

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