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Survivability and growth performance of kissing gourami (*Helostoma temminckii*) under bottle aquaponic system with artificial feed

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Abstract

This study explores the synergistic potential of Bottle Aquaponics, an integrated aquaculture-hydroponics system, in the context of sustainable food production. Focused on *Helostoma temminckii* (Kissing gourami), the research investigates the survivability and growth performance of fish under two conditions: with the inclusion of recovery food or aquaponics and without. Over a 32-day culture period, the fish exhibited consistent growth in both scenarios, with survival rates remaining at 100%. Fishes reared with the inclusion of recovery food or aquaponics (4.2 gm) showed a higher weight gain at the end of the culture period as compared to without recovery food or Aquaponics (3.9 gm). The inclusion of recovery food or aquaponics demonstrated slightly lower Feed Conversion Ratios (FCR), suggesting potential improvements in feed efficiency. Physico-chemical analyses of water revealed that the presence of recovery food or aquaponics contributed to more stable conditions, including lower ammonia levels. In contrast, conditions without recovery food or aquaponics showed higher variability in ammonia, nitrite, and nitrate concentrations. The study emphasizes the interconnected dynamics between fish growth and water quality, highlighting the potential benefits of recovery food and aquaponics in aquaculture practices. The findings underscore the potential of Bottle Aquaponics as a semi-urban farming method with low initial costs, minimal water exchange requirements, and a capacity for high-density yield. The study concludes that aquaponics, with careful management, stands as a promising solution to global food challenges, offering a novel and resourceful method for sustainable agriculture.

Keywords: Lettuce, weight, feed weight, FCR, water quality

Introduction

Aquaponics, an innovative and sustainable method of food production, integrates aquaculture and hydroponics to cultivate fish and plants in a closed-loop, recirculating system (Graber & Junge, 2009) [8]. As global water scarcity becomes a pressing issue, efficient wastewater treatment in aquaculture is imperative, particularly considering its impact on receiving water sources. As a bio-integrated method gaining traction, aquaponics combines aquaculture and hydroponics to create a revolutionary approach to food production (Hasan, 2014) [10]. The conventional agricultural practices in many regions, particularly in Asia, have led to detrimental consequences such as soil erosion, desertification, and pollution (Enduta *et al.*, 2011) [5]. The advent of aquaponics not only addresses these environmental predicaments but also offers a compelling remedy to the escalating demand for locally produced, nutritious foods. By harnessing the nutrient-rich effluent from fish, aquaponics not only provides a vital resource for plant development but ingeniously employs plants as biofilters to rejuvenate water quality (Endut *et al.*, 2010) [4]. The symbiotic relationship between aquaculture and hydroponics is underscored by the fundamental role of nitrate in ensuring optimal plant health. Intriguingly, vegetables and flowering plants of significant economic value can efficiently draw nutrients for development from nutrient-rich wastewater, given proper management and appropriate amendments. The cultivation of ornamental fish species, including Tilapia, angelfish, guppies, tetras, swordfish, mollies, and kissing gourami, has been explored in aquaponic systems (Rakocy *et al.*, 2012) [17]. Diversity takes center stage as *Helostoma temminckii*, the kissing gourami, classified in the Perciformes order and Helostomatidae family (Kottelat, 2013) [11], emerges as a filter-feeding species in midwater, further enhancing the adaptability and resilience of aquaponic systems (Ferry *et al.*, 2012) [7]. Notably Kissing gourami (*H. temminckii*), has shown promise in aquaponics due to its omnivorous nature, feeding on algae and invertebrates like chironomid larvae and insects (Ahmad and Vidthayanon, 2020) [1]. This diversity in fish species enhances the adaptability and robustness of aquaponic systems. The positive environmental impact of aquaponics extends beyond water conservation. It addresses soil degradation and pollution while promoting local economic growth through increased access to wholesome, locally produced foods (Rinehart, 2019) [18]. Additionally, studies by Rakocy *et al.* (2012) [17] and Harston (2007) [9] have demonstrated the versatility of aquaponics systems, showcasing their ability to support a wide range of plant species. Commonly cultivated plants include lettuce, basil, tomatoes, and even cool-weather vegetables like broccoli, emphasizing the system's flexibility in accommodating various crops. Aquaponics emerges as a sustainable and integrated approach to address environmental concerns, promote local food production, and contribute to economic resilience. Through the harmonious relationship between aquaculture and hydroponics, this method stands as a beacon for the future of environmentally conscious and locally focused agriculture.

2. Material and Methods

2.1 Experimental Site

Experiment on Bottle Aquaponics was conducted at hatchery wet lab of campus of Department of applied Aquaculture, Barkatullah University, Bhopal, Madhya Pradesh.

2.2 Experimental Design

The aquaponics system involved spinach (*Spinacia oleracea*) cultivation. Spinach seeds were germinated and transferred to a nursery before being placed in bottles for growth. The whole process of seed germination is depicted in Figure 1. Nutrients were provided using curry leaves extract, and a unique substrate bed was created using riverine stones. The seed bed was specifically designed to encourage the development of nitrification bacteria that are beneficial for plant growth. Subsequently, the seedlings were placed to a floating raft positioned beneath the tank (Figure 2). Fish tanks were medium-sized, accommodating 4 kissing gourami. Bottles with 1-liter capacity were used for plant growth, accommodating 2-3 seedlings per bottle. A water pump was used to uplift wastewater from the aquarium to the plant bottles, maintaining a water flow of 750 ml/min for 12 hours/day.

2.3 Growth performance

Weight (g) and length (cm) of the experimental fish was measured for the assessment of growth parameters by using electric weighing balance and scale, respectively.

Survival Rate = Total number of fishes harvested / Total number of stocked ×100

Daily Weight Gain (ADG) (g) = Mean final weight-Mean initial weight (g)

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Amount of dry feed consumed}}{\text{Live weight gain}}$$

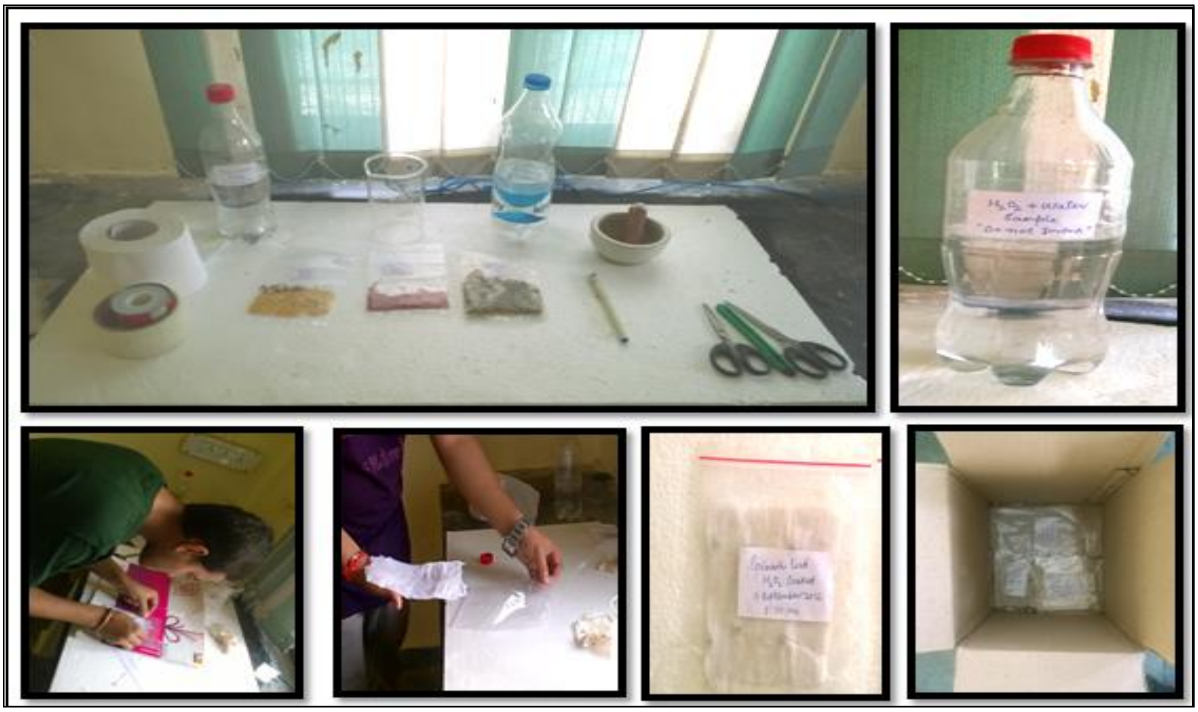
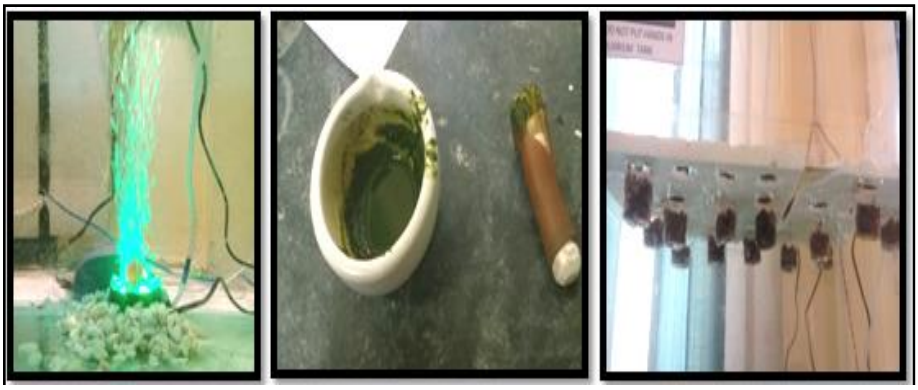


Fig 1: Material used and Steps involved in seed germination



(A) Aeration (B) Curry leaves extract (C) Floating raft.

Fig 2

2.4 Water Quality Parameters

Water quality parameters were tested by API freshwater master test kit (manufactured by: MARS fishcare, North America). These testing kit generally used for household aquarium keeping and withdraw results by comparison of colour i.e. Works as colorimeter. This individual kit contains total six bottles along with four test tubes and testing manual.

3. Results and Discussion

3.1 Growth parameters of H. temminckii with recovery food or Aquaponics

The experiment aimed to observe the growth of *H. temminckii* under different conditions, specifically with the introduction of recovery food or Aquaponics and is represented in Table 1. At the starting of the experimentation, the fish weigh 49.50 gm which showed a steady increase to a final weight of 83.10 gm at the end of the culture period. The daily feed weight also exhibited a consistent rise from 1.66 gm to 2.59 gm, with a mean feed weight per day of 2.07 gm. The total feed weight in 4 day intervals started at 6.64 gm and concluded at 10.37 gm. Weight gain, calculated ranged from 2.9 gm to 5.6 gm which had an increase till the end of the culture period. With the commencement of culture days, there is decline in FCR which varied from 2.39 to 1.85 across intervals. Importantly, the survival rate remained consistent at 100% throughout the experimental days. Ernawati *et al.* (2022) [6] reported the high survival rate of fish in the growing media treatment as compared to control is likely that the growing media supports the growth of plant roots which can filter toxic organic matter so that the water quality for fish rearing is always optimal. Mukti *et al.* (2023) [15] also indicated that survival of kissing gourami fed with different protein level had no significant effect between treatments. High fish survival indicates favorable water conditions, and the provided feed, both in quantity and quality, appears sufficient to meet the fish's needs. Diver (2006) [3] states that raising plants with fish will produce nutrients that will dissolve in the fish-rearing medium. Therefore, water as a living medium for fish must be of good quality to promote growth.

3.2 Growth parameters of H. temminckii during without recovery food or without aquaponics.

Table 2 presents the growth data of *H. temminckii* during the experiment conducted without the inclusion of recovery food or aquaponics. The initial observation at Day 0 recorded a Body Weight of 48.67 gm, with subsequent measurements taken at 4-day intervals. Over the course of the experiment, the fish exhibited consistent growth, with the final recorded body weight at Day 32 reaching 79.77 gm. The associated Feed Weight per day increased gradually (1.46 to 2.39 gm), reflecting the increasing dietary requirements of the growing fish. The Weight Gain calculated revealed progressive gains throughout the experiment i.e. 2.5 gm to 5.2 gm. FCR was computed found to be 2.01, suggesting a relatively efficient conversion of feed to body weight. Remarkably, the Survival Rate remained at 100% throughout the experiment, indicating the robust health and adaptability of the *H. temminckii* under the specified experimental conditions. This consistent survival rate is a positive indicator of the well-being and resilience of the fish population.

In comparison, both experimental conditions resulted in substantial growth of *H. temminckii*, with consistent survival rates. Fishes reared with the inclusion of recovery or aquaponics (4.2 gm) showed a higher weight gain at the end of the culture period as compared to without (3.9 gm). Amin *et al.* (2021) also suggested that the final weight of fish reared in the aquaponics system (10.29 gm) was significantly higher than that of fish reared in the conventional aquaculture system (6.63 gm) after a 30-day culture period. However, the introduction of recovery food or aquaponics (Table 1) appeared to contribute to slightly lower FCR values, indicating potential improvements in feed efficiency compared to conditions without recovery food or aquaponics (Table 2). Amin *et al.* also reported that feed conversion ratio of fish cultured in the aquaponics system was significantly better than that of fish cultured in the conventional aquaculture system. This suggests that the inclusion of recovery food or aquaponics may have positively influenced the overall growth and feed utilization efficiency of *H. temminckii*, highlighting the potential benefits of such practices in aquaculture. Similarly, weight gain, SGR, and total harvested biomass were also significantly higher in the fish reared in the aquaponics system than that of fish reared in the conventional aquaculture system. In contrast, the results of Ernawati *et al.* (2022) [6] reported that the fish reared in the aquaponics system had no significant effect on the growth in absolute length, absolute weight, and specific growth rate between treatments. However, Mao *et al.* (2023) [12] reported Higher values of Final Weight, SGR and WGR in the fish vegetable group as compared to only fish group.

3.3 Physico-chemical properties of water with and without recovery food or aquaponics

Table 3 and Table 4 present the physico-chemical properties of water under two distinct conditions: one with recovery food or aquaponics and the other without recovery food or aquaponics, respectively. In Table 3, where recovery food or aquaponics was employed, the water temperature remained relatively stable around 28.49 °C on average. The value of DO ranged between 7 to 8.5 ppm with dissolved oxygen levels consistently maintained at 7.61 ppm, whereas the pH value maintained at 7.51. During maintenance treatment of fish, the aquaponic system produces temperatures of 27.64 – 28.11 °C, dissolved oxygen5.76 – 6.14 mg/L, pH 7.15 – 7.18, which results in growth and optimal survival life as depicted by the results of Ernawati *et al.* (2022) [6]. Ammonia concentrations were consistently low with range between 0 to 1.5 ppm, while Nitrite levels fluctuated, peaking at 2 ppm while the nitrate concentrations averaged at 2.55 ppm with its value ranging between 0 to 5 ppm. Amin *et al.* concluded that nitrite and nitrate concentrations were significantly higher in aquaponics system than those of conventional aquaculture system. Portalia *et al.* (2005) [16] also reported that the average temperature during the study was 29 °C, pH was 8 and dissolved oxygen was 4 mg, in addition the ammonia concentration within the range of 0.03 to 0.53 mg/l in a lettuce based aquaponics system. Contrastingly, Table 4, representing conditions without recovery food or aquaponics, exhibited different trends. The mean water temperature was slightly higher at 28.6 °C, with Dissolved Oxygen levels averaging at 7.76 ppm and a mean pH value of 7.41. Ammonia concentrations were notably higher, averaging at 2.36 ppm, with fluctuating Nitrite levels reaching up to 3 ppm. Nitrate concentrations averaged at 3.72 ppm. The study by Tripathi *et al.* (2018) [19] demonstrated that pH and temperature values were almost same in Aquaponics and normal systems with minute fluctuations like; pH readings were 7.2 to 7.8 and 27.5 to 29.2 respectively. According to Monsees *et al.* (2017) [14] the nitrite levels in the rearing water of both systems were still below a toxic level for tilapia, <500 mg/L

In a comparative analysis, it is evident that the presence of recovery food or aquaponics (Table 3) contributed to more stable water conditions. The temperature, Dissolved Oxygen, and pH remained relatively consistent, and ammonia levels were lower compared to the conditions without recovery food or aquaponics (Table 4). The latter exhibited higher variability in these parameters, particularly in Ammonia, Nitrite, and Nitrate concentrations. The discovery of diminished ammonia concentration in this investigation is consistent with the outcomes reported by Tyson *et al.* (2004) [20], Graber and Junge (2009) [8], and Maucieri *et al.* (2018) [13]. These studies observed notably lower ammonia values in the aquaponics experimental tank when compared to the control fish tanks. Elevated ammonia levels in water can induce stress in fish and potentially lead to mortality, as emphasized in the statement by Rakocy *et al.* (2012) [17]. These findings suggest that the inclusion of recovery food or aquaponics may have had a mitigating effect on water quality parameters. The stable and lower levels of ammonia in the presence of recovery food or aquaponics indicate a potential positive impact on the aquatic environment, possibly attributed to improved waste breakdown and nutrient cycling. This comparative model sheds light on the interconnected dynamics between fish growth and the physico-chemical properties of the water environment, emphasizing the importance of considering holistic approaches in aquaculture practices.

Table 1: Growth of *H. temminckii* during the experiment (with recovery food or Aquaponics)

Days of Culture (DOC)	Body Weight (gm)	Feed weight/day With 0.200 (gm) Recovery feed	Total Feed Weight	Weight Gain (gm)	FCR	Survival rate
0	49.501	1.66	6.64	-	-	100
4	52.401	1.735	6.94	2.9	2.39	100
8	55.801	1.825	7.3	3.4	2.15	100
12	59.601	1.933	7.73	3.8	2.03	100
16	63.501	2.044	8.17	3.9	2.09	100
20	68.001	2.17	8.68	4.5	1.93	100
24	72.601	2.299	9.19	4.6	2.00	100
28	77.501	2.437	9.74	4.9	1.99	100
32	83.101	2.593	10.37	5.6	1.85	100
Mean	64.67	2.077	8.31	4.2	2.05	100

Table 2: Growth of *H. temminckii* during the Experiment (without recovery food or without aquaponics)

Days of Culture (DOC)	Body Weight (gm)	Feed weight (gm) per day	Total Feed Weight (gm)	Weight Gain (gm)	FCR	Survival rate
0	48.675	1.460	5.84	-	-	100
4	51.175	1.535	6.14	2.5	2.46	100
8	54.275	1.625	6.50	3.1	2.1	100
12	57.775	1.733	6.93	3.5	1.98	100
16	61.475	1.844	7.37	3.7	1.99	100
20	65.675	1.970	7.80	4.2	1.86	100
24	69.975	2.099	8.39	4.3	1.95	100
28	74.575	2.237	8.94	4.6	1.94	100
32	79.775	2.393	9.57	5.2	1.84	100
Mean	62.597	1.877	7.50	3.9	2.01	100

Table 3: Physico-chemical properties of water (with recovery food or Aquaponics)

Days of Culture (DOC)	Temperature (°C)	Dissolve Oxygen (ppm)	pH value	Ammonia (ppm)	Nitrite (ppm)	Nitrate (ppm)
0	28	7	7.2	0	0	0
4	28	8	7.5	0	0	0
8	27.5	8	7.6	1	0.5	1
12	28.5	8	7.6	1.5	1	1
16	29	8.5	7.8	1	1	3
20	29	8.0	7.4	1.5	1	4
24	29	7.0	7.6	1	1	4
28	29	7.0	7.4	1.5	2	5
32	28.4	7.0	7.5	1.5	1	5
Mean	28.49	7.61	7.51	1	0.83	2.55

Table 4: Physico-chemical properties of water (without recovery food or aquaponics)

Days of Culture (DOC)	Temperature (°C)	Dissolve Oxygen (ppm)	pH value	Ammonia (ppm)	Nitrite (ppm)	Nitrate (ppm)
0	28	7.2	7.2	0	0	0
4	28.2	7.6	7.6	0.25	0	0
8	27.5	7.2	7.2	2	0.5	1
12	28.9	7.7	7.7	2.5	1	2
16	29	8	7.8	3	2	4
20	29	8.2	7.2	3.5	2	4.5
24	29.2	8.4	6.8	4	3	6
28	29	7.8	7.4	3.5	2	8
32	28.6	7.8	7.8	2.5	1	8
Mean	28.6	7.76	7.41	2.36	1.28	3.72

4. Conclusion

Bottle Aquaponics is a cost-effective and low-maintenance semi-urban farming method that concurrently cultivates fish and lettuce. Utilizing nitrifying bacteria for biofiltration, it optimizes nutrient utilization without inorganic fertilizers. The system's simplicity and minimal water exchange make it appealing, especially for ornamental fish enthusiasts. This resourceful approach offers potential solutions for food shortages, even in resource-constrained areas, with high-density yields feasible on a commercial scale. Aquaponics, if carefully managed, provides distinct advantages over standalone aquaculture or hydroponics systems.

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