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Efficiency of *Moina micrura* as live food for African catfish (*Clarias gariepinus*) fry growth and survival

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Abstract The rearing of African catfish (*Clarias gariepinus*) fry heavily relies on the availability and quality of live food sources during early development stages. While *Tubifex* sp. worms have traditionally been used in aquaculture, concerns regarding pathogen transmission and environmental contamination have prompted the exploration of alternative options. The *ad libitum* feeding of *M. micrura* demonstrated the highest growth rates, with significant increase in Specific Growth Rate in weight (12.06±0.47%/day), Specific Growth Rate in length (5.13±0.6%/day), Absolute Growth Rate in length (0.07±0.003 cm/day), and Length gain (1.44±0.07) compared to other treatments. Nevertheless, the survival rate of ad libitum feeding showed no significant difference from that of different treatments. It is concluded that fry fed in *ad libitum* can reach 1-inch in length for 21 days of rearing. Additionally, based on the observations, a single fry could consume more than 50 *M. micrura* per day. However, in the first few days of feeding, a single fry could only consume 30-40 *M. micrura* per day.

Keywords: Hatchery, Length gain, Natural food, *Ad libitum*

Introduction

Philippine aquaculture is now contributing only a little over 1% of global farmed fish production compared to 5% in the year 1985 where the country was at 4th place in producing farmed fish (FAO, 2023). However, the future growth of Philippine aquaculture may not be sustained unless new markets are developed, market competitiveness is strengthened and farming risks are reduced (FAO, 2023). Aquaculture in the country is now leading in terms of production of fish with over a half of the total fisheries production in 2022 (PSA, 2023).

According to Surtida and Buendia (2000), African catfish (*Clarias gariepinus*) production is exponentially increasing, however, is low in production and its market remains undeveloped. Filipinos have readily accepted African catfish perhaps because of their familiarity with the native catfish (*C.*

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macrocephalus). The reported total production of catfish in 2022 was 2.35 million MT and grew to 2.38 million MT in 2023 (PSA, 2024).

To fill the gap between the demand and supply of the production, particularly the fingerlings that are used by the farmers, different interventions have been conducted. The use of live food, agriculture by-products and mixed live food and commercial feed were the interventions explored (Putra *et al.,* 2017; Naorbe, 2021; Enyidi *et al.,* 2017). In addition, protease-incorporated diets fed on fry and fingerlings was explored (Kemigabo *et al.,* 2019).

The African catfish larvae require a high protein level (>50%) food before they reach 5 g in size (Sanni, 2022). *Tubifex* sp. is widely used as it has a good source of protein (50-55%) and lipid (8-10%) with all essential amino acids and fatty acids (Patekar *et al.,* 2022). However, the African catfish culture industry in the Philippines faces decreasing sources of live food for fry and fingerlings during the summer season which falls on March-May. According to the collector of *Tubifex* sp. in Bulacan, Philippines during the summer season, the canals and runway of dirt from poultry and piggery farm were dried up, hence, the *Tubifex* sp. could not possibly found. According to Drossou *et al.* (2006), cultivation of live food remains costly and often does not provide a stable and safe nutritional quality of the diet, nevertheless, the aquaculture industry is still finding way to lift a sustainable aquaculture through live food production. The use of live food is accepted in the industry which is highly recognized as the main food for early life stages of fish. Live food contains all the nutrients such as proteins, lipids, carbohydrates, vitamins, minerals, amino acids and fatty acids (Raj, 2022).

Artemia sp., *Moina* sp. and *Daphnia* sp. are widely used food items among other live foods due to its convenience and availability (SEAFDEC/AQD, 2017). Aquaculture species derive a significant portion of their dietary nutrient needs from existing natural available zooplankton (El-Naggar *et al.,* 2019). The *Artemia* sp., *Moina* sp. and *Daphnia* sp. are included in these zooplanktons.

Moina sp. has been suggested to contain better source of highly unsaturated fatty acids (Watanabe *et al*., 1983). *Moina* sp. typically has a 50% dry weight protein content on average and 20-27% of dry weight is made up of fat overall (Das *et al*., 2012). Furthermore, Hanan *et al*. (2023) concluded that live *Moina* sp. could be used to replace *Artemia* sp. in the larval rearing of *Pangasius nasutus*, a catfish family, based on comparable growth performance and improved survival. Larval rearing of African catfish in aquaculture gained popularity because of its faster growth and higher pond yield. The general objective of this study was to assess the growth performance and survival of African catfish fry fed using *M. micrura* with a span of 21 days.

Materials and methods

The study was laid out in a 4 × 3 configuration using a completely randomized design (CRD). It consisted of four (4) treatments in triplicates, therefore, a total of 12 plastic containers were utilized. Each container box was provided with 40 African catfish fry. All the treatments and replicates were randomly assigned to the container boxes through draw lots.Each treatment had a different density of food given to the fry once daily as shown in Table 1. In Treatment I, 30 individuals *M. micrura* was introduced to the fry in feeding. In Treatment II, 40 individuals of *M. micrura*/fry/day were given. In Treatment III, 50 individuals of *M. micrura*/fry/day were provided. While in Treatment IV, *ad libitum* of *M. micrura* /fry/day which has an estimated count of 150 individual *M. micrura* were given.

Table 1. Density of *M. micrura* given to the fry

Treatment	Description
I	30 individuals of *M. micrura*/ fry /day
II	40 individuals of *M. micrura*/ fry /day
III	50 individuals of *M. micrura*/ fry /day
IV (control)	*Ad libitum* feeding with *M. micrura*

A total of 480 African catfish fry were obtained in a 12-piece container box. Each plastic container (30 x 22 cm) was stocked with 40 African catfish fry following the recommendation of Wenzel *et al.* (2022). Every plastic container was filled with 4 L of clean water; therefore, a 10:1 (fry/liter) ratio was considered. Each plastic container was maintained at an 8 cm water depth and also provided with an aeration system to supply the required dissolved oxygen.

The growth parameters such as AGR, SGR, length gain, and survival rate of the fry were computed using the formula below.

$$\text{Absolute growth (g/day)} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Days of culture}}$$

$$\text{Absolute growth (cm/day)} = \frac{\text{Final length} - \text{Initial length}}{\text{Days of culture}}$$

$$\text{Specific growth rate (\%/day)} = \frac{\ln(\text{Final weight}) - \ln(\text{Initial weight})}{\text{Days of culture}} \times 100$$

$$\text{Specific growth rate (\%/day)} = \frac{\ln(\text{Final length}) - \ln(\text{Initial length})}{\text{Days of culture}} \times 100$$

$$\text{Survival rate (\%)} = \frac{\text{Number of fry survived in tank}}{\text{total number of fry reared in tank}} \times 100$$

$$\text{Length gain (cm)} = \text{Final average body length} - \text{Initial average body length}$$

All data were subjected to homogeneity of variance test. The difference on growth performance was assessed using One-Way Analysis of Variance (ANOVA). The growth performance and survival of African catfish fry were subjected to comparison of means using Least Significant Difference at alpha 0.05 level of significance to identify the impact of the treatments used. Moreover, arcsine transformation was employed to transform the specific growth rate and survival rate.

Results

Result showed the growth parameters of *C. gariepinus* fry after 21 days of rearing (Table2). Treatment IV, characterized by *ad libitum* feeding using *M. micrura* (150 individuals), demonstrated the highest growth rates and survival rate among all feeding treatments. Following Treatment IV, Treatment III displayed the second-highest growth performance, where fry was provided with 50 *M. micrura*/ fry/day. The third-highest growth performance was displayed by Treatment II, where fry was provided with 40 *M. micrura*/fry/day. Lastly, Treatment I had the lowest growth performance among all the treatments where the fry was provided with 30 *M. micrura*/fry/day.

Table 2. Summary data on the mean values of Absolute Growth Rate (AGR) and Specific Growth Rate (SGR) after 21 days of rearing

Treatment	AGR (cm/day)	SGR (%/day) in length	AGR (g/day)	SGR (%/day) in weight
T I	0.04 ± 0.004^{c}	3.59 ± 0.32^{b}	0.001 ± 0.00^{b}	6.88 ± 0.84^{b}
T II	0.05 ± 0.005^{bc}	4.29 ± 0.36^{ab}	0.001 ± 0.00^{b}	6.75 ± 0.69^{b}
T III	0.05 ± 0.002^{b}	4.66 ± 0.14^{a}	0.001 ± 0.00^{b}	7.31 ± 0.59^{b}
T IV	0.07 ± 0.003^{a}	5.13 ± 0.60^{a}	0.004 ± 0.00^{a}	12.06 ± 0.47^{a}

Note: Means with the same letters in a column are statistically similar at significance level = 0.05

The growth parameters and survival rates of *C. gariepinus* after 21 days of rearing is shown in Table 3. Treatment IV demonstrated the highest value among the treatments at length gain and weight gain with the value of 1.44±0.07 cm and 0.08±0.005g, respectively. Second highest value in length and weight was obtained by Treatment III, followed Treatment II, and lastly, Treatment I. Similarly, the highest value on survival rate was obtained by Treatment IV with a value of 70.0± 0.06%, followed by Treatment III and Treatment I, and the lowest value demonstrated by Treatment II with a value of 53.33 ± 0.05%.

Table 3. Summary data on the mean values of length gain, weight gain and survival rate after 21 days of rearing

Treatment	Length Gain (cm)	Weight Gain (g)	Survival Rate (%)
T I	0.76 ± 0.08^{c}	0.03 ± 0.003^{b}	54.17± 0.21^{a}
T II	0.97 ± 0.11^{bc}	0.03 ± 0.001^{b}	53.33 ± 0.05^{a}
T III	1.07 ± 0.05^{b}	0.03 ± 0.001^{b}	60.0 ± 0.12^{a}
T IV	1.44 ± 0.07^{a}	0.08 ± 0.005^{a}	70.0 ± 0.06^{a}

Note: Means with the same letters in a column are statistically similar at significance level = 0.05.

The water quality parameters recorded within 21 days of rearing the fry on plastic containers is shown in Table 4. The dissolved oxygen recorded mean values ranges from 7.73±0.27 mg/L to 7.78±0.03 mg/L. Moreover, the pH of water ranges from 8.95±0.21 to 8.83±0.03. However, the recorded values of temperature range from 30.84±0.22C° to 30.93±0.04C°.

Table 4. Recorded dissolved oxygen, pH, and temperature of the water in the rearing plastic container per treatment

Treatment	Water Quality Parameter		
	Dissolved Oxygen (mg/L)	pH	Temperature (C°)
I	7.78 ± 0.03^{a}	8.94 ± 0.17^{a}	30.84 ± 0.22^{a}
II	7.88 ± 0.42^{a}	9.04 ± 0.25^{a}	30.88 ± 0.08^{a}
III	7.54 ± 0.11^{a}	8.83 ± 0.03^{a}	30.93 ± 0.04^{a}
IV	7.73 ± 0.27^{a}	8.95 ± 0.21^{a}	30.82 ± 0.12

Note: Means with the same letters in a column are statistically similar at significance level = 0.05

Discussion

Absolute growth rate

The AGR is the total increase in size or biomass over a given period, which offers a simple way to measure growth without being normalized to the initial size (Hopkins, 1992). The results indicated that *ad libitum* feeding (Treatment IV) significantly enhanced the growth performance of fry, both in terms of length and weight. Specifically, the fry in Treatment IV achieved an AGR of 0.068 cm/day in length and 0.004 g/day in weight, both of which were significantly higher than those in the other treatments ($p < 0.05$).

In contrast, Treatment III, which showed the second-highest growth in length, significantly differed from Treatments I, II and IV. This indicates that while Treatment III supports better growth than Treatments I and II, it is still not effective compared to *ad libitum* feeding because fry in *ad libitum* feeding had continuous access to food that allows the fry to achieve their maximum growth potential. Although Treatment III provided a good number of *M. micrura*, it might not have fully met the nutritional requirements of the fish compared to the more varied and possibly more frequent food intake in the *ad libitum* treatment. This implies that the growth rates observed in Treatments I, II, and III did not significantly differ due to the limited food availability in these treatments.

However, when the fry had unrestricted access to food (as seen in Treatment IV), they achieved significantly higher growth rates in all measured parameters. This indicates that the fry's growth potential is maximized when they are not constrained by food limitations. This finding is supported by published studies, which have consistently demonstrated that *ad libitum* feeding results in optimal growth for African catfish fry by meeting their continuous nutritional needs (Okomoda *et al*., 2019; Yiblet, 2017). The study suggests that increasing the frequency and amount of food provided to African catfish fry, specifically *Moina*, can yield significantly better growth results. This recommendation is supported by research indicating that feeding African catfish fry *ad libitum* multiple times a day results in optimal growth. Specifically, fry fed five or six times daily exhibited improved growth and nutrient utilization compared to those fed less frequently (Okomoda *et al*., 2019). By doubling the amount of food given in treatments, the uncontrolled feeding of *Moina* is effectively managed, ensuring that the fry receive consistent and sufficient nutrition. Moreover, according to Hossain *et al*. (2001), feeding catfish fry constantly, by their natural eating need, produced higher growth rates and reduced food waste compared to conventional daytime feeding.

Ad libitum feeding clearly stands out as the most effective strategy for promoting optimal growth based on the study of Okomoda *et al*. (2019). It was also concluded that *C. gariepinus* fry can achieve optimal growth when fed *ad libitum* approximately five times a day. In addition, providing continuous access to food ensures fry can consume food according to their individual needs, leading to better overall nutrient absorption and utilization. The fry must have access to food in order to be satiated (Biswas *et al*., 2006). The optimization of food intake can lead to enhanced growth and body composition (Volkoff *et al.,* 2010). Moreover, competition among fry for limited resources is minimized, this reduction in competitive stress allows fry to focus more on growth rather than survival, eliminating periods of food scarcity and optimizing growth. The data suggest that fry in other treatments experienced higher levels of stress due to competition for limited resources, leading to lower AGR compared to the treatment with *ad libitum* feeding. The reduction in competitive stress in the *ad* *libitum* feeding treatment allowed the fry to focus more on growth rather than survival, optimizing their growth rates.

Specific growth rate

According to Lugert *et al*. (2014), SGR represents the growth percentage which is advantageous for comparing growth rates among organisms with differing initial sizes. In addition, it is commonly stated as a percentage growth each day. When normalized to the size of the organism, it helps compare growth rates of various organisms or under various conditions (Trenkenshu, 2019). However, SGR values can differ considerably. For instance, Oguntuase and Adebayo (2014) documented SGR (weight) values between 0.5% and 5.5% per day for *C. gariepinus* fingerlings.

On the study conducted by Edeh *et al*. (2021), the *Heteroclarias* (crossbreed of *C. gariepinus* male and female of *Heterobranchus bidozalis*) fry that was fed using *M. micrura* showed an SGR of 6.0 %/day, it is relatively lower than the value of SGR in the *ad libitum* feeding (Treatment IV). On their experiment, they utilized 30 *Heteroclarias* fry in 50 L of water within a plastic tank, a lower SGR value observed may be attributed to the volume of water used (Craig and Helfrich, 2002).

Additionally, fish cannot exhibit the same amount of growth in weight because a portion of the energy derived from feed must be allocated to metabolic heat production, digestion, respiration, nerve impulses, maintaining salt balance, swimming, and other essential life activities (Craig and Helfrich, 2002). However, the finding of the study of Hung *et al*. (1998) shows that the basa fish (*Pangasius bocourti*) larvae fed with *Moina* exhibited lower growth performance compared to those fed with *Artemia nauplii* and *Tubifex* worms. Yet, the universally accepted value for the SGR of *C. gariepinus* is likely to end in dissatisfaction because it can be influenced by several factors. These factors include frequency, quantity, and type of feed provided can significantly impact the growth rate of fish. For instance, regular and appropriate feeding times can lead to consistent nutrient intake, which is crucial for growth (Naorbe, 2021) and other influences like light variations wherein low light intensity has been shown to impact the growth of *C. gariepinus*, as these fish typically require a dark environment for optimal development (Mbaye *et al*., 2022) and water temperature variations which can influence metabolic rates and overall physiological processes in fish (Bruton, 1979; Britz and Pienaar, 1992) which varies depending on the environment of the experimental unit. In contrast, Villegas and Lumasag (1991) noted that milkfish (*Chanos ch*anos) larvae fed with *M. macrocopa* had a higher growth rate than those fed with *B. plicatilis*, and they linked this to variations in the nutritional content of these zooplankton species. Species of zooplankton like *Branchionus plicatilis* and *Moina macrocopa* are frequently given as live food in culturing fishes because of the growth and development they offer for fish larvae. According to Watanabe *et al.* (1983), *Moina* contains crude protein levels of 59.95- 62.6% whereas *Branchionus* contains 52.15-60.57. This variation affects the SGR of the fry according to nutritional content on the live foods.

Length gain

A critical factor in assessing the growth performance of *C. gariepinus* fry is length gain since grow-out operators often rely on length measurements as a standard practice for assessing the growth and development of African catfish. By providing continuous access to food, this treatment ensures optimal nutrient intake, reduces competition and stress, and minimizes cannibalism, which contribute to enhanced growth performance in *C. gariepinus* fry (Duk *et al.,* 2017). Faster growth is acquired by providing more food. Generally, greater food consumption results in faster growth (Goodrich and Clark, 2023). Moreover, Hossain *et al*. (2001) added that comparing continuous feeding or feeding at night based on needs to feeding three meals a day resulted in higher growth development.

The fry must have access to food to be satiated which leads to better growth (Biswas *et al*., 2006). Furthermore, the results showed that longer gains were associated with larger densities of *M. micrura* given to the fry. The more food given resulted on better growth in terms of length. Relatively, Liu and Fu (2017) noted that food availability significantly affects fish growth. In addition, Marimuthu *et al.* (2010) demonstrates that feeding frequency can significantly impact growth of *C. gariepinus* fry. As demonstrated in Treatment IV, ad libitum feeding allows fry to eat continually. This ensures that the fry receives enough food for growth, this feeding practice encourages a greater length gain of the fry. Unrestricted access to food probably lessens stress, minimizes rivalry among the fry, and maximizes nutritional intake all of which contribute to improved growth. Relatively, the results of Marimuthu *et al.* (2010) provide support to the observation that fish growth is greatly influenced by feeding frequency or availability of food. Sufficient nourishment guarantees that the fish receive enough nutrients to aid in their growth.

Survival rate

The highest survival rate was obtained by the fry in Treatment IV. Nevertheless, the results showed that all the treatments were not significantly different. Although the differences in survival percentages among the treatments appear substantial, according to Kraemer and Blasey (2016) the actual effect size might be insufficient to reach statistical significance, The study also utilized arcsine transformation analysis to further examine the survival rates of African catfish fry when fed different amounts of *Moina micrura*.

Furthermore, it is important to remember that several factors, such as cannibalism-induced mortality, natural mortality, and light conditions might affect aquaculture survival rates. In relation, during the conduct of this study, cannibalism was observed. The survival rates in each treatment group, ranging from 50%-70%, were likely affected by cannibalistic behaviour. Nonetheless, the type of cannibalism observed was head-first cannibalism, which was also observed in the study of Hecht and Appelbaum (1988) that cannibalism in African catfish fingerlings can occur in either tail-first or head-first forms. Although cannibalism is a natural behaviour in catfish, it can be reduced by using appropriate management techniques, such as keeping stocking densities at ideal levels and making sure there is enough food available. Treatment IV or ad libitum feeding during the experiment likely reduced the possibility of cannibalism by providing the fry with sufficient food or until satiation. This approach not only promoted higher growth rates but also improved survival rates. On the other hand, the findings from Orina *et al*. (2016) highlight the importance of environmental factors, such as light and temperature, on the survival and growth of *C. gariepinus* fry. The observed 82% survival rate under dark conditions and a stable water temperature of 28°C suggests that these factors create a conducive environment for the fry. Along with Wubie and Dagne (2022), dark environments can reduce stress and aggressive interactions among fry, as many fish species exhibit less territorial behavior and aggression in lower light also, darkness may reduce visibility for potential predators, thus lowering predation risks.

Water quality parameter

Water quality is a major factor in determining the production of cultured fish. It is essential that different water quality parameters are monitored and managed to sustain the growth and survival offish (Davies and Ansa, 2007). Fish respiration and metabolic processes require a minimum concentration of 5-6 mg/L of DO (Extance, 2022) the comparatively high DO levels seen in every treatment 7.54-7.88 mg/L indicate that oxygen availability was not a limiting factor in the study. In addition, DO levels should not be too high because gas bubbles disease could happen to fish (Towers, 2014). Gas bubble disease can affect the fry's buoyancy (Velázquez-Wallraf *et al*., 2022), and fry food intake could also be affected (Fish Pathology, 2020).

Furthermore, the pH range observed in the study was a little higher than the acceptable range of 6.5-8.5 (Irfan and Ginting, 2022). According to Boyd (1989), a pH range of 7.5-8.5 was optimum for the culture of fishes. Fish may die at a pH of less than 5.0, become stressed, and have restricted development and reproduction in water with a pH range of 4.0-6.5 or 9.0-11.0 (Tumwesigye *et al*., 2022).

Moreover, ensuring a stable temperature within this specific range supports the development of a robust and efficient metabolism, leading to optimal growth and overall health (Akinwole and Faturoti, 2007). The temperature range that was measured in this study was within the 26°-32°C ideal range for the greatest growth of *C. gariepinus* fry (Kasihmuddin *et al.,* 2021). The whole growth, digestion, and metabolic processes of the fry are supported by ideal temperatures. Fish weight and size are significantly positively impacted by water temperature, according to Tumwesigye *et al*. (2022), with an increase in temperature of one unit being correlated with an increase in catfish weight and size.

In addition, good water quality conditions were combined with the *ad libitum feeding* schedule in Treatment IV, which produced the highest AGR and survival rate. With constant access to food and ideal water quality, the fry was able to reach its full potential for growth and continued high survival rates. According to this, the optimal growth performance in *C. gariepinus* fry can only be attained by combining *ad libitum* feeding with carefully controlled water quality conditions. Considering culture expenses, the affordability and ease of culturing *M. micrura*, carry significant implications. *M. micrura* is one of the most cost-effective natural food solutions for aquaculture operations due to its low production costs and simple culture requirements. By utilizing *M. micrura* as a natural food source, hatchery operators can effectively manage costs while supporting the growth of African catfish fry.

The study recommended the enhancement of *M. micrura* fed on the fry. The cultured *M. micrura* utilized in the study was solely fed using yeast. This limitation suggests the exploration on different food given to *M. micrura*. By giving nutrient-rich food such phytoplankton could enrich *M. micrura*, it becomes a more potent source of essential nutrients, including proteins, lipids, vitamins, and minerals, which are crucial for the growth and development of fish fry.

In addition, the study recommended to utilize both *M. micrura* produced in the outdoor and indoor setup. The indoor culture setup likely provides a controlled environment, on the other hand, the outdoor setup might offer a more natural diet and environmental conditions that could improve the nutritional quality of *M. micrura*. Natural sunlight and exposure to a wider variety of microorganisms and algae in outdoor cultures could result in healthier, more nutritious zooplankton, potentially enhancing the growth and health of the fry.

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Conflicts of interest

The authors declare no conflict of interest.

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