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FATTY ACID BIOENCAPSULATION IN *Daphnia* sp. TO ENHANCE THE GROWTH AND SURVIVAL OF CATFISH (*Clarias* sp.) LARVAE

Bioenkapsulasi Asam Lemak Pada *Daphnia* sp. Untuk Meningkatkan Pertumbuhan dan Sintasan Larva Ikan Lele (*Clarias* sp.)

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ABSTRACT

This study aimed to evaluate the effectiveness of fatty acid bioencapsulation in *Daphnia* sp. on the growth performance and survival rate of catfish (*Clarias* sp.) larvae. The research was conducted in May 2025 at the Hatchery Facility of the Sukabumi Campus, IPB University, using an experimental method with a Completely Randomized Design (CRD) consisting of three treatments and three replicates. The treatments included a control treatment (P0) 0.6 g L^{-1} yeast, fish oil enrichment (P1) 0.1 mL L^{-1} fish oil + 0.6 g L^{-1} yeast, and corn oil enrichment (P2) 0.1 mL L^{-1} corn oil + 0.6 g L^{-1} yeast. Three-day-old catfish larvae were reared for seven days and fed bioencapsulated *Daphnia* sp. The observed parameters included survival rate (SR), absolute length growth, and water quality parameters (temperature and pH). Data were analyzed using Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) at a 95% confidence level. The results demonstrated that bioencapsulation of *Daphnia* sp. using fish oil (P1) produced the best performance in catfish larvae. The fish oil treatment (P1) resulted in the highest survival rate of 85.8 ± 6.52%, followed by the corn oil treatment (P2) at 78.2 ± 5.39%, and the control at 70.2 ± 3.69%. The highest absolute length growth (ALG) was also observed in the fish oil treatment (P1), reaching 0.287 ± 0.047 cm. Therefore, bioencapsulation of *Daphnia* sp. using fish oil has the potential to serve as an effective nutritional strategy for improving the quality of catfish seed production.

Keywords: Bioencapsulation, Catfish Larvae, *Daphnia* sp., Fish Oil, Survival Rate

ABSTRAK

Penelitian ini bertujuan menganalisis efektivitas bioenkapsulasi asam lemak pada *Daphnia* sp. terhadap pertumbuhan dan sintasan larva ikan lele (*Clarias* sp.). Penelitian dilaksanakan pada bulan Mei 2025 di Hatchery Kampus IPB Sukabumi menggunakan metode eksperimen dengan Rancangan Acak Lengkap (RAL) yang terdiri atas tiga perlakuan dan tiga ulangan. Perlakuan yang diuji meliputi kontrol (P0) ragi 0,6 g L^{-1}, pengayaan minyak ikan (P1) 0,1 mL L^{-1} + ragi 0,6 g L^{-1}, dan pengayaan minyak jagung (P2) 0,1 mL L^{-1} + ragi 0,6 g L^{-1}. Larva ikan lele

berumur tiga hari dipelihara selama tujuh hari dan diberi pakan *Daphnia* sp. hasil bioenkapsulasi. Parameter yang diamati meliputi *survival rate* (SR), pertumbuhan panjang mutlak, serta kualitas air berupa suhu dan pH. Data dianalisis menggunakan ANOVA dan dilanjutkan *Duncan Multiple Range Test* (DMRT) pada taraf kepercayaan 95%. Hasil penelitian menunjukkan bahwa bioenkapsulasi *Daphnia* sp. menggunakan minyak ikan (P1) memberikan hasil terbaik terhadap performa larva ikan lele. Perlakuan minyak ikan (P1) menghasilkan SR tertinggi sebesar 85,8 ± 6,52%, diikuti minyak jagung (P2) sebesar 78,2 ± 5,39%, dan kontrol sebesar 70,2 ± 3,69%. Pertumbuhan panjang mutlak tertinggi juga diperoleh pada perlakuan minyak ikan (P1) sebesar 0,287 ± 0,047 cm. Dengan demikian, bioenkapsulasi *Daphnia* sp. menggunakan minyak ikan berpotensi menjadi strategi nutrisi yang efektif untuk meningkatkan kualitas benih ikan lele.

Kata Kunci: Bioenkapsulasi, Larva Ikan Lele, *Daphnia* sp., Minyak Ikan, Sintasan

INTRODUCTION

Catfish (*Clarias* sp.) is one of the leading freshwater fish commodities in Indonesia with high economic value and continuously increasing market demand. This commodity is widely cultured due to its relatively rapid growth, high environmental tolerance, and simple cultivation techniques that can be applied across various production scales. According to data from the Indonesian Ministry of Marine Affairs and Fisheries (2023), national catfish production has continued to increase and has become one of the major contributors to freshwater aquaculture production in Indonesia. Ministry of Marine Affairs and Fisheries West Java is one of the primary production centers, with a total production reaching 289,362 tons in 2023. The increasing market demand for catfish has consequently driven the need for high-quality seed production to support the sustainability of the aquaculture sector.

The success of catfish aquaculture is strongly influenced by seed quality, particularly during the larval stage, which represents a critical phase in the production cycle. The survival rate of catfish larvae in Indonesia remains relatively low, averaging only 40–60% (KKP, 2023). Low larval survival is generally associated with the limited development of the digestive system, the low physiological capacity of larvae to utilize nutrients efficiently, and suboptimal feed quality during the early rearing phase. In addition, slow larval growth frequently becomes a major constraint in catfish hatchery operations, thereby reducing overall seed production efficiency (Siswanto *et al.,* 2023).

One of the strategies to improve the performance of catfish larvae is through the use of high-quality live feed enriched with essential nutrients. Live feed is known to possess several advantages over artificial feed because it is more easily digested, contains natural enzymes, and exhibits active movement that can stimulate the feeding response of fish larvae (Juliana *et al.,* 2016). Furthermore, live feed plays an important role in supporting the development of digestive organs and enhancing nutrient absorption efficiency during the early stages of fish development.

Daphnia sp. is one of the zooplankton species widely utilized as live feed for freshwater fish larvae due to its body size, ranging from approximately 0.2–5 mm, which is suitable for the mouth opening of fish larvae. In addition, *Daphnia* sp. is easy to culture and contains relatively high protein levels. According to Sarmudianto (2015), the protein content of Daphnia sp. ranges from approximately 42–58%, while lipid content ranges from 6–8%, making it potentially beneficial for supporting the growth and survival of fish larvae. Moreover, enrichment of *Daphnia* sp. using specific nutrient sources has been reported to improve the nutritional quality of live feed and enhance the growth performance of cultured fish larvae (Casiraghi et al., 2024). However, the essential fatty acid content of *Daphnia* remains relatively

limited; therefore, nutritional enrichment is required to improve its biological quality as larval feed.

Essential fatty acids, particularly omega-3 and omega-6 fatty acids, play important roles in supporting growth, tissue development, energy metabolism, and the immune system of fish larvae. Deficiency of essential fatty acids during the larval stage may result in impaired growth, developmental abnormalities, and reduced survival rates, as fatty acids are essential components in metabolic processes and tissue development (de Carvalho & Caramujo, 2018). In modern aquaculture, bioencapsulation techniques through live feed enrichment have become one of the most widely developed approaches to improve the nutritional content of live feed organisms prior to their administration to fish larvae.

This study utilized fish oil, corn oil, and yeast as fatty acid enrichment sources for *Daphnia* sp. Fish oil is known to contain long-chain omega-3 polyunsaturated fatty acids such as EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid), which play important roles in growth, tissue development, and the improvement of larval quality in cultured fish (Darwisito et al., 2008). Broodstock diets supplemented with 40 g kg^{-1} fish oil have been reported to produce better egg and larval quality in Nile tilapia (*Oreochromis niloticus*) compared to treatments without fish oil supplementation. Corn oil, on the other hand, contains linoleic acid (omega-6), which is involved in cell membrane formation and supports metabolic processes related to larval growth (Mokoginta et al., 2002). The use of these lipid sources in *Daphnia* sp. enrichment has been shown to increase the survival rate of Nile tilapia larvae up to 92.5%. In addition, yeast supplementation is known to enhance protein content and improve the nutritional quality of live feed because yeast contains protein, B-complex vitamins, and bioactive compounds that support the growth of live feed organisms (Siswanto et al., 2023).

Several recent studies have reported that enrichment of live feed using fatty acid sources can improve the growth and survival of both freshwater and marine fish larvae. Putra et al. (2024) stated that the nutritional quality of live feed significantly affects growth performance and energy utilization efficiency in fish larvae. Furthermore, Sarmudianto (2015) demonstrated that enrichment of Daphnia sp. using fish oil as a lipid source increased the omega-3 fatty acid content of live feed from 0.58% to 3.64%, thereby improving the nutritional quality of zooplankton to support fish larval development.

Nevertheless, studies concerning the bioencapsulation of *Daphnia* sp. using combined fatty acid sources on the performance of catfish (*Clarias* sp.) larvae remain relatively limited. Therefore, this study is important to evaluate the effectiveness of *Daphnia* sp. enrichment using fatty acid sources as an effort to enhance the growth and survival rate of catfish larvae in an optimal and sustainable manner.

RESEARCH METHODS

Time and Location of the Study

This study was conducted May 2025 at the Hatchery Facility of the Sukabumi Campus, IPB University, located on Sarasa Street, Sukabumi City, West Java, Indonesia. The research activities included preparation of rearing containers, live feed enrichment, larval rearing, growth observation, survival rate measurement, and monitoring of water quality parameters throughout the experimental period.

Tools and Materials

The equipment used in this study included aquaria measuring 30×30×30 cm, glass jars, aerators, aeration hoses, air stones, plankton nets, a blender, measuring cylinders, a thermometer, and a pH meter.

The materials used consisted of three-day-old catfish (*Clarias* sp.) larvae with an average length of 0.6 cm, *Daphnia* sp., reservoir water, yeast, fish oil, corn oil, and egg yolk as enrichment materials.

Experimental Design

This study employed an experimental method using a Completely Randomized Design (CRD) consisting of three treatments with three replicates, resulting in a total of nine experimental units. The treatments tested in this study were as follows:

- P0 (Control): yeast at 0.6 g L^{-1}
- P1: fish oil at 0.1 mL L^{-1} + yeast at 0.6 g L^{-1}
- P2: corn oil at 0.1 mL L^{-1} + yeast at 0.6 g L^{-1}

Research Procedures

Preparation of Rearing Containers

The rearing containers in the form of aquaria were first cleaned using freshwater until all surfaces were free from dirt and contaminants. The aquaria were subsequently dried and filled with 10 L of reservoir water as the rearing medium. Each aquarium was equipped with an aeration system to maintain dissolved oxygen stability throughout the larval rearing period.

Live Feed Enrichment Process

The enrichment of *Daphnia* sp. was carried out using a bioencapsulation method referring to the live feed enrichment technique using fish oil described by Sarmudianto (2015), which was applied to enhance the omega-3 fatty acid content of *Daphnia* sp.

In the control treatment (P0), the enrichment solution consisted of 100 mL of water and yeast at 0.6 g L^{-1}. P1 treatment consisted of 100 mL of water, yeast at 0.6 g L^{-1}, fish oil at 0.1 mL L^{-1}, and egg yolk at 0.01 mL L^{-1}. P2 treatment consisted of 100 mL of water, yeast at 0.6 g L^{-1}, corn oil at 0.1 mL L^{-1}, and egg yolk at 0.01 mL L^{-1}. All ingredients were blended until a homogeneous mixture was obtained.

The enrichment solution was then transferred into glass jars containing 2L of freshwater and continuously aerated. A total of 4,000 individuals of *Daphnia* sp. were introduced into each enrichment container and maintained for six hours. After the enrichment process was completed, the *Daphnia* were harvested using a plankton net and immediately administered to the fish larvae as experimental feed.

Larval Rearing and Feeding

Catfish larvae were reared for seven days at a stocking density of 20 individuals L^{-1} in 10 L of rearing media. The enriched *Daphnia* sp. were provided at a density of 400 individuals per rearing container using a restricted feeding method.

Feeding was carried out three times daily at 07:00, 13:00, and 18:00 WIB. Periodic feeding management was applied to improve feed consumption efficiency and minimize water quality deterioration caused by feed residues.

Water Quality Management and Observation

The water quality parameters observed during the study included temperature and pH. Measurements were conducted three times daily at 07:00, 13:00, and 18:00 WIB throughout the rearing period. Temperature measurements were performed using a thermometer, while pH measurements were conducted using a digital pH meter. Water quality monitoring was performed to ensure that the rearing media remained within the optimal range for the growth and survival of catfish larvae (Boyd, 2015).

Observation Parameters

Survival Rate

Survival rate was calculated based on the percentage of fish remaining alive at the end of the rearing period compared to the initial stocking number. The survival rate (SR) was calculated according to Yustianti et al. (2013):

$$SR = (Nt / N_0) \times 100\%$$

Where:

- SR = Survival rate (%)
- Nt = Number of fish at the end of the rearing period (individuals)
- N_0 = Number of fish at the beginning of the rearing period (individuals)

Absolute Length Growth

Absolute length growth was calculated based on the difference between larval length at the end and at the beginning of the rearing period. Length measurements were performed from the tip of the head to the tip of the tail using a sampling method. The calculation of absolute length growth followed Effendie (1997):

$$ALG = Lt - L_0$$

Where:

- ALG = Absolute length growth (cm)
- Lt = Fish length at the end of the rearing period (cm)
- L_0 = Fish length at the beginning of the rearing period (cm)

Data Analysis

The research data were analyzed using One-Way Analysis of Variance (ANOVA) at a 95% confidence level. Prior to the analysis of variance, the data were subjected to normality and homogeneity tests to ensure that the statistical assumptions were met. If the ANOVA results indicated significant differences among treatments ($P < 0.05$), Duncan's Multiple Range Test (DMRT) was subsequently performed to determine specific differences among treatments. All data were analyzed using SPSS software. Data collection was conducted using a sampling technique based on the observed parameters.

RESULT

Survival Rate (SR)

Survival rate (SR) is one of the primary indicators of successful fish larval rearing because it reflects the ability of larvae to adapt to the environment, utilize feed efficiently, and maintain physiological conditions throughout the rearing period. The survival rate parameter of catfish larvae is presented in Figure 1.

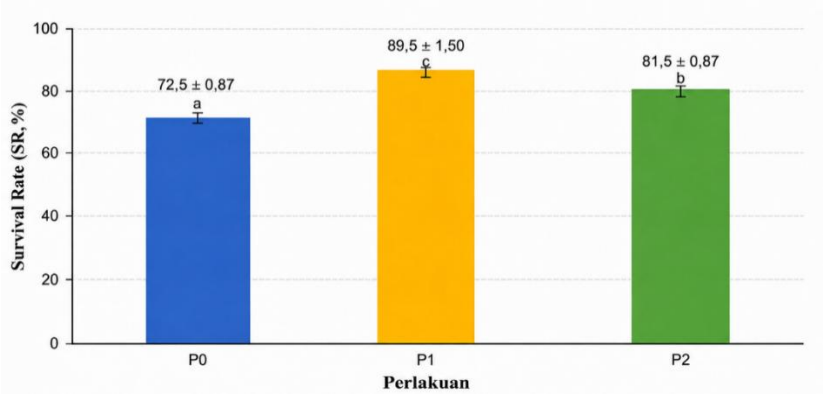

Figure 1. Survival Rate (SR, %) of Catfish (*Clarias* sp.) Larvae Under Different *Daphnia* sp. Enrichment Treatments During a 7-day Rearing Period. P0 = Yeast (Control); P1 = Yeast + Fish Oil; P2 = Yeast + Corn Oil. Data Are Presented as Mean ± Standard Deviation (n = 3). Different Superscript Letters Indicate Significant Differences Based on Duncan's Multiple Range Test ($P < 0.05$)

Absolute Length Growth

Absolute length growth is one of the important indicators in evaluating fish larval performance because it reflects the success of metabolic processes, nutrient utilization, and tissue development during the rearing period. The absolute length growth values of catfish larvae reared for seven days are presented in Figure 2 and showed varying results.

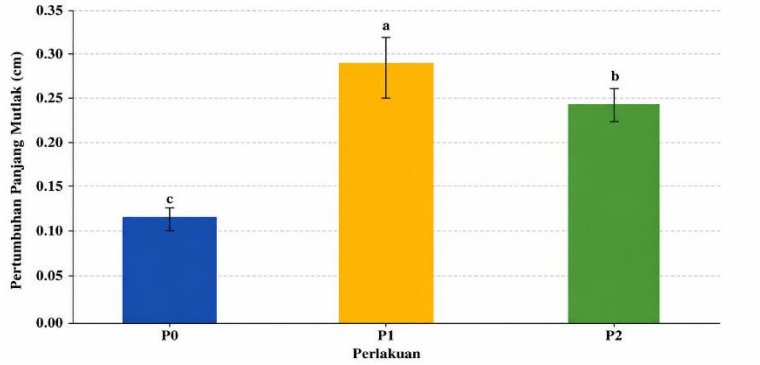

Figure 2. Absolute Length Growth (ALG) of Catfish (*Clarias* sp.) Larvae Under Different *Daphnia* sp. Enrichment Treatments During the Rearing Period. P0 = Yeast (Control); P1 = Yeast + Fish Oil; P2 = Yeast + Corn Oil. Data Are Presented as Mean ± Standard Deviation (n = 3). Different Superscript Letters Indicate Significant Differences Based on Duncan's Multiple Range Test at a 95% Confidence Level ($P < 0.05$).

Water Quality

Water temperature during the study ranged from 24–31°C in the control treatment (P0), while temperatures in treatment P1 (fish oil) ranged from 24.5–30°C, and treatment P2 (corn oil) ranged from 25–28°C. The pH values recorded during the study ranged from 6.8–8.8. The results of water quality measurements during the seven-day catfish larval rearing period are presented in Table 3.

Table 3. Mean Values of Water Quality Parameters in the Rearing Media of Catfish (*Clarias* sp.) Larvae During the 7-day Rearing Period

Treatment	Temperature (°C)	pH	Optimal Range
P0	27.33 ± 0.76	8.08 ± 0.37	
P1	27.25 ± 0.66	7.82 ± 0.08	Temperature: 25–32°C; pH: 6.5–9
P2	27.00 ± 0.50	8.22 ± 0.32	

Description: P0 = enrichment with yeast at 0.6 g L^{-1} (control); P1 = enrichment with yeast at 0.6 g L^{-1} + fish oil at 0.1 mL L^{-1} + egg yolk at 0.01 mL L^{-1}; P2 = enrichment with yeast at 0.6 g L^{-1} + corn oil at 0.1 mL L^{-1} + egg yolk at 0.01 mL L^{-1}. Data are presented as mean ± standard deviation (n = 3). The optimal ranges of water quality parameters refer to Boyd (2015) and SNI 6484.5:2014.

DISCUSSION

The results of this study demonstrated that enrichment of *Daphnia* sp. using fatty acid sources affected the survival improvement of catfish (*Clarias* sp.) larvae. Treatment P1 (yeast + fish oil) produced the highest SR value of 85.8 ± 6.52%, followed by treatment P2 (yeast + corn oil) at 78.2 ± 5.39%, whereas the control treatment (P0) only resulted in an SR value of 70.2 ± 3.69%. These findings indicate that enrichment of live feed using lipid sources was able to improve the physiological performance of larvae compared to treatments without oil supplementation. This condition suggests that essential fatty acid content in live feed plays an important role in supporting larval metabolism and physiological resistance.

High survival rate indicates that feed quality and rearing media conditions are capable of optimally supporting the nutritional and metabolic requirements of fish larvae (Mopangga et al., 2023). Maulana et al. (2024) stated that temperature stability is highly important during the larval phase because optimal temperatures can enhance larval growth and survival. In a study on snakehead fish (*Channa striata*) larvae, a temperature treatment of 30°C produced a specific growth rate of 16.84% per day and a survival rate of 95.56%, whereas unsuitable temperature fluctuations caused physiological stress in fish larvae.

The increase in SR values observed in treatment P1 was presumably associated with the increased energy and essential fatty acid contents of *Daphnia* sp. following the bioencapsulation process. The addition of fish oil in the enrichment media is known to increase lipid and energy contents in live feed organisms, thereby allowing larval energy requirements for metabolic activities and growth to be fulfilled more optimally. Lipids represent a major energy source with high energy density and play an important role in supporting larval physiological activities, particularly during the early developmental stage when the digestive system has not yet fully developed. According to Mokoginta et al. (2002), enrichment of *Daphnia* sp. using lipid sources was able to improve the growth and survival of Nile tilapia (*Oreochromis niloticus*) larvae because lipids function as a primary energy source, thereby enabling protein utilization to be directed more efficiently toward tissue formation and larval growth. The enrichment treatment resulted in survival rates reaching 92.5%, which was higher than the non-enriched treatment at approximately 75%.

In addition to serving as an energy source, fish oil also contains polyunsaturated fatty acids (PUFAs), particularly EPA (Eicosapentaenoic Acid) and DHA (Docosahexaenoic Acid), which are highly required by fish larvae. Omega-3 fatty acids are known to play important roles in maintaining cell membrane integrity, enhancing neural tissue development, strengthening immune responses, and increasing larval tolerance to environmental stress (de Carvalho & Caramujo, 2018). According to Suprayudi et al. (2005), EPA and DHA are essential fatty acids critically required during the larval phase because they play significant roles in the development of vital organs and in supporting fish larval growth. *Artemia* enriched with EPA

and DHA contained 28 g kg^{-1} EPA and 70 g kg^{-1} DHA, resulting in better larval growth compared to non-enriched treatments.

The findings of this study showed that bioencapsulation of *Daphnia* sp. positively affected the growth and survival of catfish (*Clarias* sp.) larvae. The improvement in larval performance was presumably associated with enhanced nutritional quality of live feed following the enrichment process, particularly increased levels of amino acids and essential fatty acids, which are important for supporting metabolism, tissue formation, and energy utilization efficiency in fish larvae. These results are consistent with the findings of Putra et al. (2024), who reported that improvements in live feed nutritional quality could increase energy utilization efficiency and improve the physiological performance of freshwater fish larvae. Furthermore, Casiraghi et al. (2024) reported that enrichment of *Daphnia* sp. using amino acids increased the survival rate of Nile tilapia (*Oreochromis niloticus*) larvae to 86.67%, which was higher than the non-enriched treatment at 73.33%. Mokoginta et al., (2002) also stated that enrichment of *Daphnia* sp. using various oil sources improved the growth and survival of Nile tilapia larvae, where fish oil enrichment increased the n-3 fatty acid content in *Daphnia* sp. thereby supporting larval development and growth more effectively. Susanti et al. (2015) similarly reported that enrichment of *Daphnia* sp. using corn oil improved the survival rate of climbing perch (*Anabas testudineus*) larvae up to 96.67%, which was higher than the treatment without enrichment. Similar findings were also reported by Siswanto et al. (2023), who demonstrated that enrichment of *Daphnia* sp. using Viterna produced better growth and survival performance in post-larval papuyu fish (*Anabas testudineus*) compared to non-enriched treatments. Therefore, bioencapsulation of live feed has been proven to improve the nutritional quality of *Daphnia* sp., making it more effective in supporting the growth and survival of catfish larvae.

Treatment P2 also showed higher SR values compared to the control treatment. This result was presumably due to the presence of linoleic acid (omega-6) in corn oil, which plays a role in supporting metabolism and tissue growth in fish larvae. Consequently, enrichment of *Daphnia* sp. using corn oil was able to improve the growth performance and survival of Nile tilapia larvae (Mokoginta et al., 2002). According to Sarmudianto (2015), enrichment of *Daphnia* sp. using fish oil increased the omega-3 fatty acid content in live feed, thereby supporting fish larval growth and development more optimally. This condition indicates that fish larvae have relatively high omega-3 fatty acid requirements during the early developmental phase to support tissue growth and cell differentiation.

Based on Duncan's multiple range test, treatment P1 showed a tendency to differ significantly from the control treatment (P0), but not significantly from treatment P2. These findings indicate that both oil sources were capable of improving larval survival; however, fish oil produced a better biological response compared to corn oil. This result differs from the findings of Susanti et al. (2015), who reported that enrichment of *Daphnia* sp. using corn oil produced the highest survival rate in climbing perch larvae. Differences among studies may be attributed to species-specific nutritional requirements, enrichment dosages, and the physiological capacity of organisms to utilize certain types of fatty acids. Essential fatty acid requirements are known to vary depending on fish species and developmental stages (Suwirya et al., 2003).

In addition to nutritional factors, the effectiveness of the enrichment process is also influenced by the concentration of enrichment materials used. Excessively high oil concentrations may cause the body surface of *Daphnia* sp. to become coated with oil layers, thereby inhibiting movement and respiration of the live feed organisms. Such conditions may reduce the biological quality of *Daphnia* before being administered to fish larvae. Similar findings were reported by Sarmudianto (2015), who stated that increasing fish oil concentration

in enrichment media enhanced the fatty acid content of *Daphnia* sp., but could also reduce the survival rate of the live feed organisms.

Overall, the SR results showed that bioencapsulation of *Daphnia* sp. using fish oil has the potential to serve as an effective nutritional strategy for improving live feed quality and supporting the successful production of catfish (*Clarias* sp.) seed during the larval phase. This approach is considered practical and has potential application in hatchery-scale operations to improve productivity and efficiency in freshwater fish seed production.

The *Daphnia* sp. enriched with fish oil showed a positive response in the absolute length growth of catfish larvae. Based on the results of this study, enrichment of *Daphnia* sp. using fatty acid sources significantly affected the absolute length growth of catfish (*Clarias* sp.) larvae. Treatment P1 produced the highest absolute length growth value of 0.287 ± 0.047 cm, followed by treatment P2 at 0.227 ± 0.035 cm, whereas the control treatment (P0) showed the lowest value of 0.117 ± 0.015 cm. The ANOVA results indicated that the treatments had a significant effect on absolute length growth ($P < 0.05$). Duncan's multiple range test further demonstrated that treatments P1 and P2 differed significantly from the control treatment (P0), but did not differ significantly from each other.

The high absolute length growth (ALG) observed in treatment P1 was presumably associated with the increased essential fatty acid and energy contents in *Daphnia* sp. following fish oil bioencapsulation. The higher lipid content in the live feed likely enabled larvae to obtain sufficient energy, allowing dietary protein to be utilized more efficiently for tissue growth and cell formation processes. According to Sarmudianto (2015), increasing the omega-3 fatty acid content in *Daphnia* sp. through fish oil enrichment improved the energy quality of live feed, thereby optimizing fish larval growth.

Length growth during the larval stage generally occurs rapidly due to intensive cell division and differentiation processes that support the formation of fish organs and body tissues (Effendie, 1997). According to Mulqan et al. (2017), fish growth is influenced by internal factors such as physiological and genetic capacity, as well as external factors including environmental quality and feed nutrient availability.

Fish oil is known to be rich in omega-3 fatty acids, particularly EPA (Eicosapentaenoic Acid) and DHA (Docosahexaenoic Acid), which play essential roles in tissue development, cell membrane formation, and growth metabolism in fish larvae. These fatty acids also function in improving cell membrane flexibility and metabolic enzyme activity, thereby enhancing nutrient absorption efficiency in larval bodies (de Carvalho & Caramujo, 2018). According to Darwisito et al. (2008), feed containing fish oil as a source of n-3 fatty acids improved the quality of Nile tilapia (*Oreochromis niloticus*) larvae because it supported tissue formation and larval organ development. Fish oil supplementation at 40 g kg^{-1} feed produced better egg and larval quality compared to lower dosages.

In addition to improving energy metabolism efficiency, live feed enrichment was also presumed to enhance the biological quality of *Daphnia* sp. as larval feed. Enriched live feed organisms possess more complete nutritional compositions, thereby supporting optimal physiological development of fish larvae. Putra et al. (2024) stated that the nutritional quality of live feed significantly influences the growth rate and tissue development of freshwater fish larvae. Similar findings were reported by Mokoginta et al. (2002), who demonstrated that enrichment of *Daphnia* sp. using lipid sources increased the survival rate of Nile tilapia (*Oreochromis niloticus*) larvae up to 92.5% in the corn oil enrichment treatment, compared to approximately 75% in the non-enriched treatment. Furthermore, the enrichment process increased the essential fatty acid content in *Daphnia* sp., thereby supporting larval growth more effectively.

Treatment P2 also resulted in higher absolute length growth compared to the control treatment. This finding indicates that the linoleic acid (omega-6) contained in corn oil was still

capable of supporting fish larval growth. Omega-6 fatty acids play important roles in cell membrane formation and metabolic processes associated with growth and tissue development in fish larvae (de Carvalho & Caramujo, 2018). Nevertheless, the results demonstrated that growth in treatment P2 remained lower than that in treatment P1. This condition suggests that omega-3 fatty acid requirements during the catfish larval stage are more dominant than omega-6 requirements, particularly in supporting tissue formation and growth metabolism.

The lowest absolute length growth observed in the control treatment (P0) was presumably caused by the low essential fatty acid content in non-enriched *Daphnia* sp. Limited energy and lipid contents in the live feed likely caused dietary protein utilization to be directed more toward basic metabolic requirements rather than tissue growth. According to Suprayudi et al. (2005), the essential fatty acids EPA and DHA in live feed play crucial roles in supporting the growth and development of aquatic organism larvae. *Artemia* enriched with EPA and DHA contained 28 g kg^{-1} EPA and 70 g kg^{-1} DHA, thereby improving larval growth and survival performance more effectively compared to non-enriched treatments.

Overall, the ALG results of this study showed that bioencapsulation of *Daphnia* sp. using fish oil produced the best growth response in catfish (*Clarias* sp.) larvae. This live feed enrichment technology has the potential to become an effective nutritional strategy for improving seed quality and enhancing the productivity of freshwater fish hatcheries in a sustainable manner.

In addition to nutritional factors, larval length growth is also influenced by rearing environmental quality. Stable water quality conditions throughout the study were presumed to contribute to the optimization of catfish larval growth. Environmental parameters such as temperature and pH within optimal ranges can enhance metabolic activity, feeding response, and nutrient absorption efficiency in fish (Boyd, 2015).

The results of water quality observations indicated that the rearing media remained within optimal ranges to support the growth and survival of catfish (*Clarias* sp.) larvae. Water temperatures in the control treatment (P0) ranged from 24–31°C, treatment P1 (fish oil) ranged from 24.5–30°C, while treatment P2 (corn oil) ranged from 25–28°C. The pH values throughout the study ranged from 6.8–8.8. These ranges are still consistent with water quality standards for catfish aquaculture according to the Indonesian National Standard (SNI 6484.5:2014) and Boyd (2015), which state that the optimal temperature range for tropical freshwater fish culture is 25–32°C with an optimal pH range of 6.5–9.

Temperature plays an important role in fish physiological activities. Excessively low or high temperatures may negatively affect fish appetite and overall performance. Lestari & Dewantoro (2018) stated that rearing temperatures below 25°C or above 32°C could inhibit the growth of catfish larvae and potentially reduce their physiological condition. In addition to affecting appetite and growth, temperature also influences metabolic processes, immune responses, and reproductive capacity in fish. Unsuitable temperatures may induce physiological stress, increase susceptibility to disease, and reduce survival rates. Therefore, maintaining temperature within the optimal range is essential to support successful larval rearing, particularly during the larval phase, which is highly sensitive to environmental fluctuations. Temperature fluctuations directly influence metabolic rate, enzymatic activity, oxygen consumption, feeding response, and nutrient utilization efficiency in fish. Low temperatures slow down metabolic processes and reduce feed consumption, whereas excessively high temperatures increase respiratory energy demands and may trigger physiological stress.

The relatively stable temperature conditions observed throughout the study were presumed to be one of the supporting factors contributing to the high growth and survival rates of larvae in all treatments. Temperature stability helps maintain metabolic balance and improve the efficiency of energy utilization derived from feed. According to Buwono et al. (2019), the

larval stage represents a critical period in fish development because the digestive system is not yet fully developed; therefore, larvae require live feed that is easily digested, appropriately sized according to mouth opening, and nutritionally rich to support growth and survival. In that study, administration of *Daphnia magna* produced a specific growth rate of 2.7% per day in koi fish larvae, with a survival rate reaching 50.67%. Furthermore, Lestari & Syukriah (2020) reported that stable aquaculture environmental conditions could suppress physiological stress responses in fish, thereby allowing more metabolic energy to be allocated toward growth processes rather than environmental adaptation mechanisms. Reduced stress conditions consequently improve nutrient utilization efficiency and growth performance in cultured fish.

In addition to temperature, the degree of acidity (pH) is also an important parameter in fish larval culture because it is closely related to physiological processes, osmoregulation, enzymatic activity, and ionic balance within the fish body. The pH values observed during the study ranged from 6.8–8.8 and remained within the tolerance range of catfish larvae. According to Putri & Kurniawan (2023), optimal water quality conditions, particularly pH, are highly important in fish larval rearing because they affect metabolic processes, nutrient utilization efficiency, and larval survival. In their study, a pH range of 7.5–8.3 was still capable of supporting optimal physiological conditions in fish larvae. Excessively low pH levels may disrupt ionic balance and damage gill tissues, whereas excessively high pH levels may increase ammonia toxicity within the rearing media. The relatively stable pH conditions observed throughout the study were also presumed to support nutrient absorption and metabolic activity in the larvae.

Based on the water quality observations, no substantial differences in environmental parameters were detected among treatments. This finding indicates that differences in absolute length growth and survival rate of catfish larvae were more likely influenced by the nutritional quality of enriched *Daphnia* sp. rather than by environmental conditions of the rearing media. Therefore, enrichment of live feed using fatty acid sources, particularly fish oil, has strong potential to become a major factor in improving the physiological performance of catfish larvae during the early rearing phase.

CONCLUSION

Bioencapsulation of *Daphnia* sp. using fatty acid sources affected the growth and survival of catfish (*Clarias* sp.) larvae. The fish oil enrichment treatment produced the best performance, with a survival rate of 89.5 ± 1.5% and an absolute length growth of 0.287 ± 0.047 cm. The corn oil treatment also improved growth and survival compared to the control treatment; however, the results remained lower than those obtained with fish oil enrichment.

The improvement in larval performance was presumably associated with the high omega-3 fatty acid content, particularly EPA and DHA, in fish oil, which play important roles in enhancing metabolic efficiency, tissue development, and larval resistance. Water quality conditions throughout the study remained within optimal ranges, thereby supporting successful catfish larval rearing.

Overall, the bioencapsulation technology of *Daphnia* sp. using fish oil has potential application as a strategy to improve the quality of live feed in catfish hatchery operations in order to produce seed with better growth performance and survival rates.

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REFERENCES

Buwono, N. R., Mahmudi, M., Sabtaningsih, S. O., & Lusiana, E. (2019). Analisis daya cerna pakan alami pada larva ikan koi. *Indonesian Green Technology Journal, 8(1), 17–24.* https://doi.org/10.21776/ub.igtj.2019.008.01.03

Boyd, C. E. (2015). *Water quality: An introduction*. Cham: Springer International Publishing.

Casiraghi, P. J., Mulyani, S., & Aqmal, A. (2024). Pengaruh pemberian Daphnia sp. yang diperkaya asam amino terhadap pertumbuhan dan sintasan larva ikan nila *Oreochromis niloticus*. *Journal of Aquaculture and Environment, 7(2).* https://doi.org/10.35965/jae.v7i2.5088

Darwisito, S., Zairin Jr., M., Sjafei, D. S., Manalu, W., & Sudrajat, A. O. (2008). *Feeding broodstock on a diet containing vitamin E and fish oil improve eggs and larval quality of Nile tilapia (Oreochromis niloticus)*. *Jurnal Akuakultur Indonesia, 7(1), 1–10.* https://doi.org/10.19027/jai.7.1-10

de Carvalho, C. C. C. R., & Caramujo, M. J. (2018). The various roles of fatty acids. *Molecules*, *23(10), 2583*. https://doi.org/10.3390/molecules23102583

Effendie, M. I. (1997). *Biologi perikanan*. Yogyakarta: Yayasan Pustaka Nusatama.

Juliana, S., Rosyadi, R., & Agusnimar, A. (2016). Kelulushidupan dan pertumbuhan larva ikan baung (Hemibagrus nemurus) diberi cacing sutra (*Tubifex tubifex*) yang diperkaya dengan probiotik dan habbatussauda (*Nigella sativa*). *Dinamika Pertanian, 32(1), 75–86.*

Kementerian Kelautan dan Perikanan. (2023). *Statistik perikanan budidaya Indonesia tahun 2023*. Jakarta: KKP RI.

Lestari, D. F., & Syukriah. (2020). Manajemen stres pada ikan untuk akuakultur berkelanjutan. *JAMI: Jurnal Ahli Muda Indonesia, 1(1), 95–102*. https://doi.org/10.46510/jami.v1i1.23

Maulana, R. A., Aryani, N., & Sukendi. (2024). Interaksi fotoperiod dan temperatur terhadap performa pertumbuhan dan sintasan larva ikan gabus *(Channa striata)*. *Ilmu Perairan (Aquatic Science), 13(2), 158–166*. https://doi.org/10.31258/jipas.13.2.158-166

Mokoginta, I., Jusadi, D., & Pelawi, T. L. (2002). The effect of enriched Daphnia sp. with different source of oil on the survival rate and the growth of Oreochromis niloticus larvae. *Jurnal Akuakultur Indonesia, 2(1), 7–11*. https://doi.org/10.19027/jai.2.7-11

Mopangga, R., Tuiyo, R., & Syamsuddin, S. (2023). Pengaruh pemberian pakan alami Daphnia sp. dengan dosis yang berbeda terhadap pertumbuhan dan kelangsungan hidup benih ikan mas *(Cyprinus carpio)*. *Journal of Fisheries Agribusiness, 1(1), 33–40.*

Mulqan, M., Rahimi, S. A. E., & Dewiyanti, I. (2017). Pertumbuhan dan kelangsungan hidup benih ikan nila gesit *(Oreochromis niloticus)* pada sistem akuaponik dengan jenis tanaman yang berbeda. *Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah, 2(1), 183–193.*

Mulqan, M., Sayyid, A. E. R., & Irma, D. (2017). Pertumbuhan dan kelangsungan hidup benih ikan nila *Oreochromis niloticus* pada sistem resirkulasi. *Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah, 2(1), 56–65.*

Putra, D. A., Hidayat, T., & Kusuma, R. I. (2024). Kualitas nutrisi pakan alami terhadap performa pertumbuhan larva ikan lele *Clarias* sp. *Jurnal Akuakultur Tropis, 9(1), 12–21.*

Putra, P. R. S., Karina, I., & Imtihan, I. (2024). Analisis kandungan gizi pada produk diversifikasi olahan ikan lele *(Clarias gariepinus)*. *SEMAH Jurnal Pengelolaan Sumberdaya Perairan, 8(1), 65–73.*

Putri, M. N., & Kurniawan, R. (2023). Kualitas air pada media pemeliharaan larva ikan kakap putih *(Lates calcarifer)*. *South East Asian Aquaculture*, *1(1), 1–4*. https://doi.org/10.61761/seaqu.1.1.1-4

Sarmudianto, E. (2015). Peningkatan kadar asam lemak omega-3 pada *Daphnia* sp. dengan pengkayaan minyak ikan. *Jurnal Mina Sains*, *1(1), 1–5*. https://doi.org/10.30997/jms.v1i1.168

Siswanto, S., Aminah, S., Sofarini, D., & Nopitasari, N. (2023). *Efektivitas* pengayaan Daphnia sp. dengan viterna untuk post larva ikan papuyu (*Anabas testudineus* Bloch). *Rekayasa*, *16(3), 378–386*. https://doi.org/10.21107/rekayasa.v16i3.23210

Suprayudi, M. A., Takeuchi, T., & Hamasaki, K. (2005). Effect of enriched *Artemia* sp. by EPA (Eicosapentaenoic Acid; C20:5n-3) and DHA (Docosahexaenoic Acid; C22:6n-3) on survival rate of swimming crab *Portunus pelagicus*. *Jurnal Akuakultur Indonesia*, 4(1), 15–21. https://journal.ipb.ac.id/index.php/jai/article/view/3995

Suwirya, K., Giri, N. A., & Marzuqi, M. (2003). Pengaruh N-3 HUFA pakan terhadap pertumbuhan benih kerapu macan (*Epinephelus fuscoguttatus*). *Jurnal Penelitian Perikanan Indonesia, 9(4), 19–24*. http://dx.doi.org/10.15578/jppi.9.4.2003.19-24

Yustianti, M. N., Ibrahim, M. N., & Ruslaini. (2013). Pertumbuhan dan sintasan larva ikan lele *Clarias* sp. dengan pemberian pakan alami berbeda. *Jurnal Mina Laut Indonesia*, *1(1), 56–64*.