Effect of black soldier fly (*Hermetia illucens*) larvae oil addition in feed on the growth performance and survival of milkfish (*Chanos chanos*)

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Abstract. This study evaluated the effects of dietary addition of black soldier fly (BSF) (*Hermetia illucens*) larvae oil on the growth performance and survival of juvenile milkfish (*Chanos chanos*). A total of 150 fish, with an average initial weight of 6.74±0.2 g, were assigned to six treatment groups receiving different inclusion levels of BSF larvae oil: 0 mL (control), 1.5 mL, 2 mL, 2.5 mL, 3 mL, and 3.5 mL per 100 g of feed. Growth parameters assessed included weight gain (WG), total feed consumption (TFC), feed conversion ratio (FCR), feed utilization efficiency (FUE), specific growth rate (SGR), and survival rate (SR). Statistical analysis revealed that larvae oil addition had a significant effect ($p < 0.05$) on all measured parameters. The optimal performance was observed in the group receiving 1.5 mL of BSF larvae oil, with a WG of 94.24±0.36 g, TFC of 236.84±3.27 g, FCR of 2.38±0.01, FUE of 39.78±4.00%, SGR of 1.94± 0.15% day^{-1}, and SR of 96.67±5.77%. These findings suggest that the addition of BSF larvae oil at 1.5 mL per 100 g of feed enhances growth and feed efficiency in milkfish.

Key Words: alternative fish feed, aquaculture nutrition, fish diets, insect-derived ingredients, maggot oil.

Introduction. Milkfish (*Chanos chanos*) is a widely consumed fish species in Indonesia, appreciated for its platable taste and high nutritional value (Nusantari et al 2016). It contains 20.53 g/100 g of protein and 14.2% omega-3 fatty acids, while also being low in cholesterol (Prabowo et al 2017). Additionally, milkfish exhibits favorable aquaculture characteristics such as euryhalinity, rapid growth, high disease resistance, and tolerance to environmental fluctuations (Vasava et al 2018). Economically, milkfish commands a relatively high market price, ranging from IDR 19,000 to IDR 30,000 per kilogram (Herawati et al 2020).

One of the primary challenges in aquaculture is feed management. Feed accounts for approximately 60-70% of total production costs in fish farming (Herawati et al 2020; Bakar et al 2021). To ensure optimal fish growth and health, feed must be nutritionally balanced and provide adequate levels of protein, lipids, carbohydrates, vitamins, and minerals. Among these nutrients, lipids play a crucial role by serving as a dense energy source and supplying essential fatty acids necessary for physiological development and metabolic functions (Xu et al 2021). Fish oil is traditionally regarded as the optimal lipid source due to its high omega-3 fatty acid content (Shin et al 2011). However, declining capture fisheries has led to reduced fish oil availability and rising prices (Fernandes et al 2018). This situation prompting the need to explore alternative lipid sources to replace fish oil in aquafeeds formulations for milkfish.

Black soldier fly (BSF) (*Hermetia illucens*) larvae oil (often called maggot oil), obtained through extraction processes, is rich in medium-chain fatty acids such as lauric acid (21-49%) (Fawole et al 2021), and also contains essential polyunsaturated fatty acids, including linoleic acid (3.6-4.5%) and linolenic acid (0.08-0.74%) (Li et al 2016).

Furthermore, BSF larvae possess a high nutritional profile, with protein content ranging from 40 to 45% and lipid content between 26 and 35% (Nogales-Mérida et al 2019). Studies have shown that maggots fed on oil-rich organic waste can yield lipid levels as high as 42-49% (Bakar et al 2021). Given these nutritional and functional attributes, BSF larvae oil represents a promising alternative lipid source for aquafeeds. However, information on its effects on milkfish diets remains limited. Therefore, the present study was conducted to evaluate the effects of dietary supplementation of BSF larvae oil on the growth performance and survival of juvenile milkfish (*Chanos chanos*). Specifically, this study aimed to determine the optimal inclusion level of BSF larvae oil that enhances weight gain, feed utilization, and survival rate.

Material and Method

***Material**.* The experimental animal used were juvenile milkfish with an average weight of 6.74±0.2 g fish^{-1}, maintained at a stocking density of 1 fish/3 L of water (Haryati 2011). A total of 150 fish were used, obtained from the Center for Brackish Water Aquaculture (BBPBAP), Jepara, Indonesia. The rearing period lasted for 45 days, from January to March 2025, during which the fish were fed artificial diets supplemented with varying levels of BSF larvae oil. The amount of feed given was 5% of the total fish biomass/day, with the feed given three times a day, at 07.00, 12.00, and 17.00 Western Indonesian Time, using a fixed feeding rate method.

***Method**.* This study was conducted from January to March 2025. A completely randomized design was employed, consisting of six treatments with three replications each. The treatments consisted of different levels of BSF larvae oil added per 100 g of feed, as follows:

- A: 0 mL BSF larvae oil addition (control);
- B: 1.5 mL BSF larvae oil addition;
- C: 2.0 mL BSF larvae oil addition;
- D: 2.5 mL BSF larvae oil addition;
- E: 3.0 mL BSF larvae oil addition;
- F: 3.5 mL BSF larvae oil addition.

The selection of dosage levels was based on the study by Xu et al (2021), which identified 2.5 mL as the optimal BSF larvae oil addition dose for enhancing the specific growth rate (SGR) in carp. The proximate composition of the feed ingredients and the detailed feed formulation are presented in Tables 1 and 2, respectively.

***Test feed**.* The feed used in the study was formulated artificial feed. The preparation process began with the selection of raw materials based on the nutritional requirements of juvenile milkfish. A proximate analysis of the feed ingredients was conducted using Microsoft Excel to ensure alignment with the nutritional needs of milkfish at the grow-out stage. The proximate composition of the feed ingredients is presented in Table 1.

Table 1

Proximate composition of feed ingredients

Ingredients	*Components (%)*						*Total (%)*
	Moisture	*Protein*	*Nitrogen-free extract*	*Fat*	*Crude fiber*	*Ash*	
Fish meal*	8.65	45.70	12.27	6.18	3.26	23.94	100
Corn bran**	10.54	0.40	88.18	0.61	0.03	0.24	100
Shrimp head meal***	11.98	30.45	4.69	2.87	5.26	44.75	100
Soybean meal***	8.93	46.20	31.92	2.99	3.16	6.80	100
Rice bran*	11.48	6.36	30.13	1.59	34.77	15.67	100

Note: *Hernowo et al (2020); **Wibowo et al (2017); ***Sudrajat & Effendi (2002).

According to Marwan et al (2022), juvenile milkfish (5-15 g) require a minimum dietary protein level of 25%. In this study, the formulated feed contained 30% protein. The complete feed formulation used during the experiment is shown in Table 2.

Table 2

Feed formulation for milkfish

Feed ingredients	*Feed composition (%/100 g feed)*					
	A	*B*	*C*	*D*	*E*	*F*
Fish meal	26.00	26.00	26.00	26.00	26.00	26.00
Shrimp head meal	6.00	6.00	6.00	6.00	6.00	6.00
Soybean meal	26.60	26.60	26.60	26.60	26.60	26.60
Corn barn	9.90	9.90	9.90	9.90	9.90	9.90
Rice bran	21.00	21.00	21.00	21.00	21.00	21.00
Fish oil	3.50	2.00	1.50	1.00	0.50	0.00
BSF larvae oil	0.00	1.50	2.00	2.50	3.00	3.50
Corn oil	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin-mineral mix	3.00	3.00	3.00	3.00	3.00	3.00
CMC	2.00	2.00	2.00	2.00	2.00	2.00
Total (%)	100.00	100.00	100.00	100.00	100.00	100.00
Protein (%)	30.13	30.13	30.13	30.13	30.13	30.13
Nitrogen-free extract (%)	30.04	30.04	30.04	30.04	30.04	30.04
Fat (%)	8.77	8.77	8.77	8.77	8.77	8.77
Energy (kcal g^{-1})*	374.36	374.36	374.36	374.36	374.36	251.19
E/P**	12.42	12.42	12.42	12.42	12.42	8.34

Notes: *Energy values were calculated based on digestible energy according to Watanabe (1988) for 1 g of protein is 5.6 kcal g^{-1}, 1 g of carbohydrate is 4.1 kcal g^{-1} and 1 g of fat is 9.4 kcal g^{-1}; **The E/P ratio for optimal fish growth ranges between 8-12 kcal g^{-1} (De Silva 1988); CMC = carboxymethylcellulose; E/P = energy to protein ratio.

Data collection. The observed variables included weight gain (WG), total feed consumption (TFC), feed conversion ratio (FCR), feed utilization efficiency (FUE), specific growth rate (SGR), and survival rate (SR).

Weight Gain (WG). According to Zonneveld et al (1991), WG can be calculated using the following formula:

$$WG = W_t - W_0 \qquad (1)$$

where: WG = weight gain (g);
W_t = final body weight (g);
W_0 = i
nitial body weight (g).

Total feed consumption (TFC). Feed consumption values, according to Zonneveld et al (1991), can be calculated using the following formula:

$$TFC = F_1 + F_2 + \ldots + F_n \qquad (2)$$

where: TFC = total feed consumption (g);
F1 = amount of feed on the first day (g);
F2 = amount of feed on the second day (g);
F3 = amount of feed on the nth day (g).

Feed conversion ratio (FCR). According to Zonneveld et al (1991), FCR can be calculated using the formula:

$$FCR = \frac{F}{(W_t + D) - W_0} \qquad (3)$$

where: FCR = feed conversion ratio;
F = amount of feed provided during maintenance (g);
W_t = fish weight at the end of the study (g);
W_0 = fish weight at the start of the study (g);
D = biomass of fish that died during maintenance (g).

Feed Utilization Efficiency (FUE). According to Zonneveld et al (1991), FUE can be calculated using the following formula:

$$\text{FUE} = \frac{W_t - W_0}{F} \times 100 \qquad (4)$$

where: FUE =feed utilization efficiency (%);
W_t = fish weight at the end of the study (g);
W_0 = fish weight at the start of the study (g);
F = amount of feed provided during maintenance (g).

Specific growth rate (SGR). According to Zonneveld et al (1991), the SGR can be calculated using the following formula:

$$\text{SGR} = \frac{\text{Ln } W_t - \text{Ln } W_0}{t} \times 100 \qquad (5)$$

where: SGR = specific growth rate (% day^{-1});
W_t = fish weight at the end of the study (g);
W_0 = fish weight at the start of the study (g);
T = length of the maintenance period (days).

Survival rate (SR). According to Zonneveld et al (1991), the formula for calculating the SR of milkfish is as follows:

$$\text{SR} = \frac{N_t}{N_0} \times 100 \qquad (6)$$

where: SR = survival rate (%);
N_t = number of fish at the end of the study;
N_0 = number of fish at the beginning of the study.

Water quality parameters. Water quality parameters measured in this study included temperature (°C), pH, salinity (ppt), and dissolved oxygen (mg L^{-1}). All parameters were measured twice daily, in the morning and evening. Temperature and dissolved oxygen were recorded using a Horiba U water quality checker (WQC), salinity was measured with an ATAGO refractometer, and pH was determined using a pH meter from Eutech Instruments.

Data analysis. The collected data were statistically analyzed using the SPSS software. Normality, homogeneity, and linear regression tests were conducted prior to further analysis. The results were then subjected to analysis of variance (ANOVA). If ANOVA indicated a significant effect ($p < 0.05$), Duncan's multiple range test was performed to determine significant differences between treatments. Water quality data were analyzed descriptively and compared against standard reference values for aquaculture feasibility.

Proximate composition analysis. The protein, fat, ash, carbohydrate, fiber, and moisture contents of the samples were determined through proximate composition analysis following AOAC (2005) guidelines. Protein content was measured using the Kjeldahl method, while fat content was analyzed using the Soxhlet extraction method. Moisture and ash contents were determined using gravimetric methods. Carbohydrate content was calculated by difference, based on proximate composition data, while crude fiber content was determined using the acid–base hydrolysis method (Weende method).

Results. The highest WG was observed in treatment B, with an average of 94.24±0.36 g. The lowest WG was recorded in treatment F, at 65.50±8.42 g. The WG values observed during the study are presented in Figure 1.

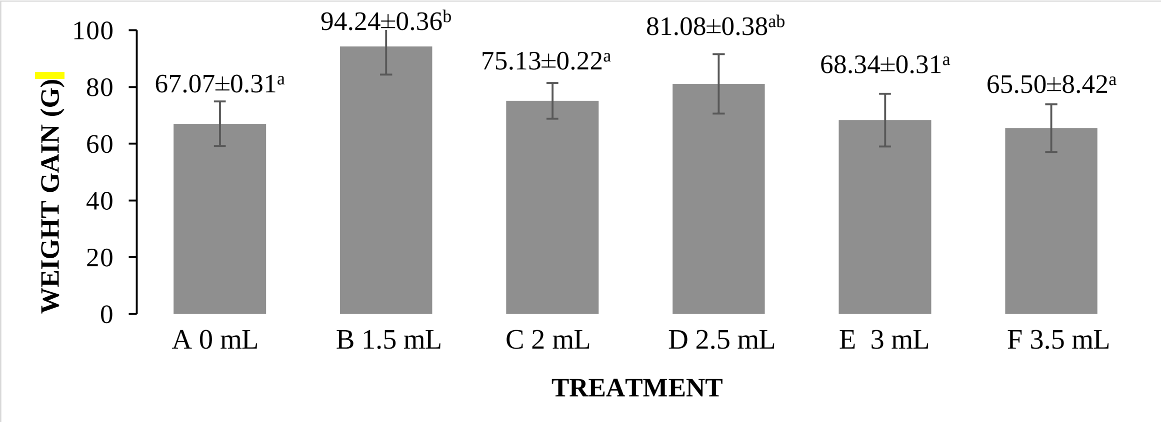

Figure 1. Weight gain values during the study. Different superscript letters show significant differences between treatments.

Furthermore, the highest TFC was observed in the treatment B, at 236.84±3.27 g. The lowest TFC was recorded in the treatment F, at 205.36±10.81 g. The TFC values observed during the study are presented in Figure 2.

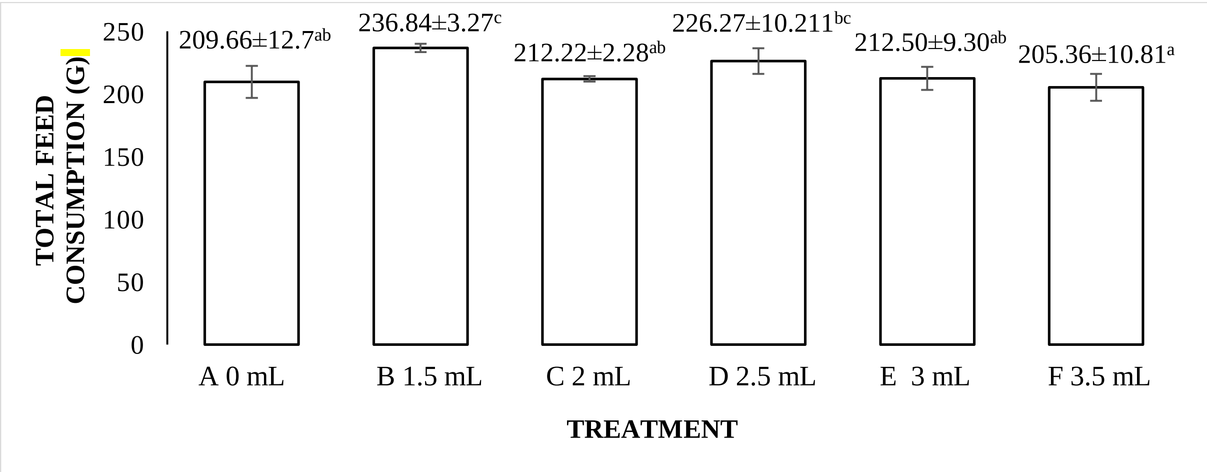

Figure 2. Total feed consumption during the study. Different superscript letters show significant differences between treatments.

Based on the research conducted, the FUE values varied across treatments. The highest FUE was observed in the treatment B, reaching 39.78±4.00%, while the lowest FUE occurred in the treatment F, with a value of 31.82±2.57%. The FUE values during the study are presented in Figure 3.

Based on the research conducted, the FCR results were obtained. The lowest (best) FCR was found in the treatment D, with a value of 2.36±0.05. The highest (least favorable) FCR was recorded in the treatment F, with a value of 2.52±0.04. The FCR during the study is presented in Figure 4.

Based on the research conducted, the highest SGR was observed in the treatment B, reaching 1.94±0.15% day^{-1}. The lowest SGR was found in the treatment F, which was 1.50±0.13% day^{-1}. The SGR values during the study are presented in Figure 5.

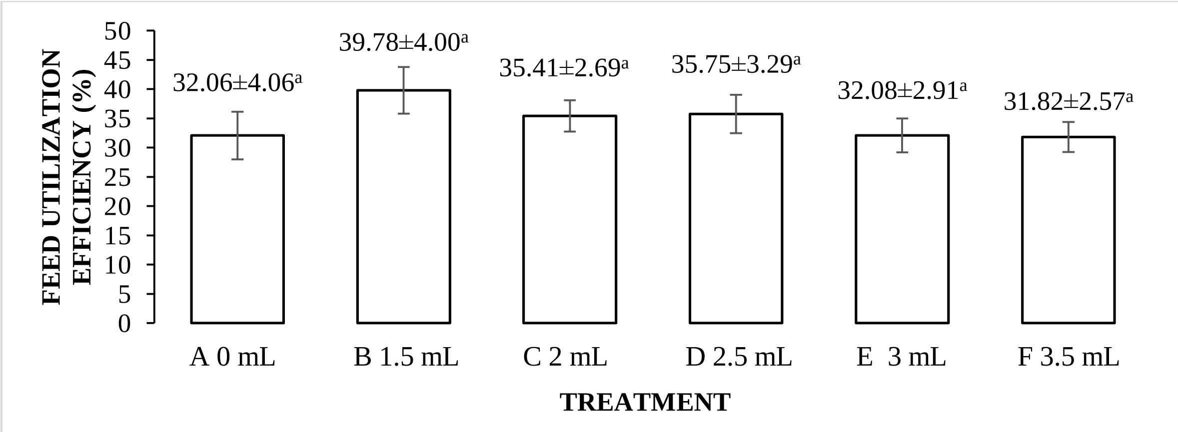

Figure 3. Feed utilization efficiency during the study. Same superscript letters show insignificant differences between treatments.

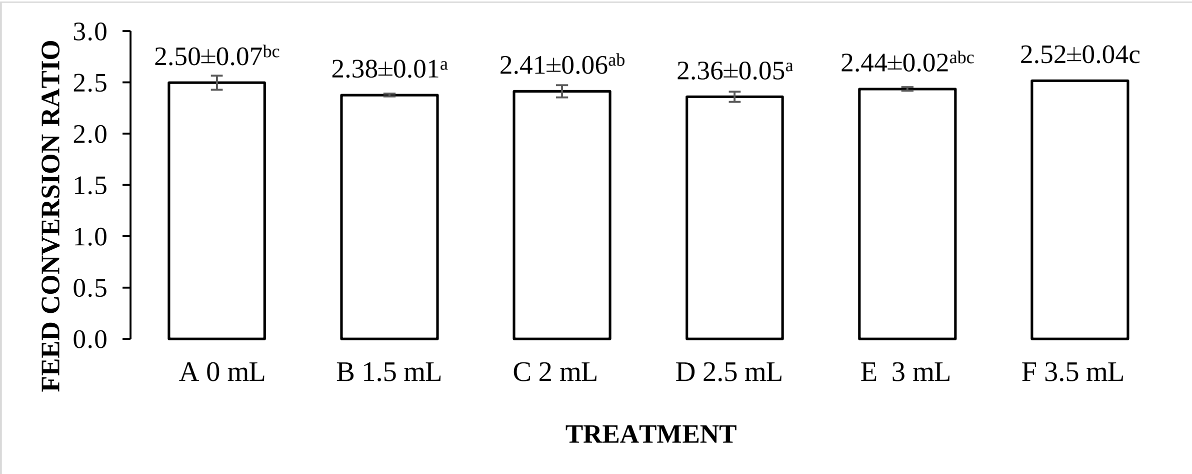

Figure 4. Feed conversion ratio during the study. Different superscript letters show significant differences between treatments.

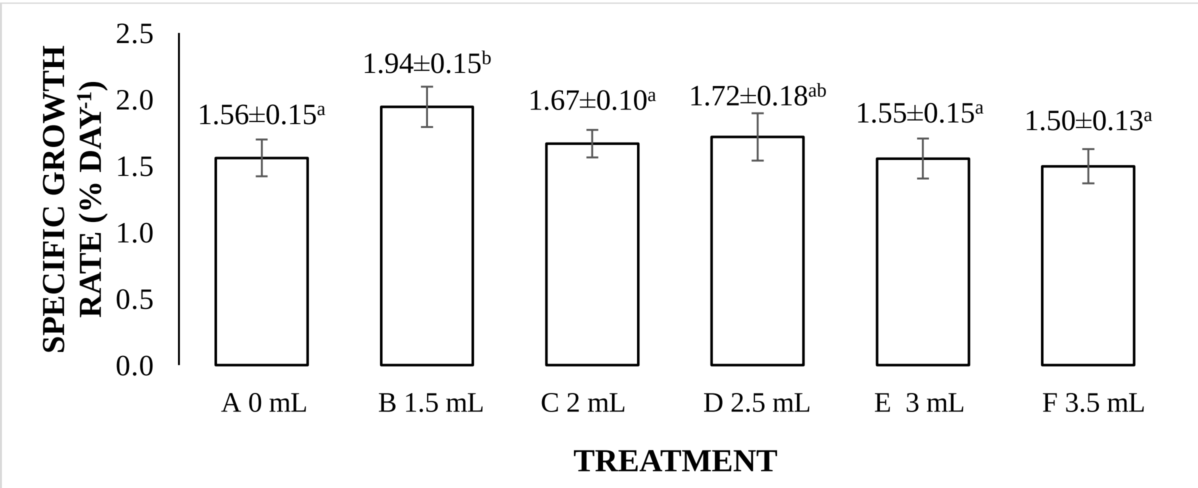

Figure 5. Specific growth rate during the study. Different superscript letters show significant differences between treatments.

Based on the conducted research, the highest SR was observed in the treatment B, at 96.67±5.77%. The lowest survival rates, all at 83.33±5.77%, were found in treatments A, E, and F. The SR during the study is presented in Figure 6.

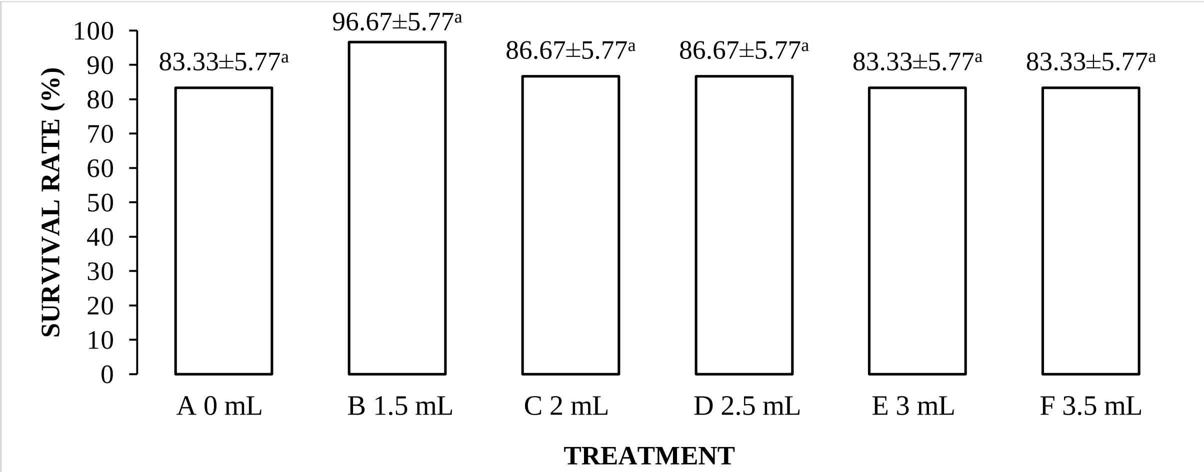

Figure 6. Survival rate of the fish during the study. Different superscript letters show significant differences between treatments.

Water quality significantly affects the growth and survival of milkfish. The measured water quality parameters include temperature, dissolved oxygen, pH, and salinity. The results of these measurements during milkfish maintenance are presented in Table 3.

Table 3

Results of water quality measurements during the study

No	*Variable*	*Unit*	*Results*	*Acceptable range*
1	Temperature	°C	26.30-28.50	24-31*
2	Dissolved oxygen	mg L^{-1}	3.53-5.96	> 3**
3	pH	-	7.9-8.2	7.0-8.5***
4	Salinity	ppt	26-27	15-35**

Note: *Cardoso et al (2020); **Herawati et al (2020); ***Indonesian National Standard (SNI) 6148.3:2013.

The results of water quality measurements during the study indicated that the water parameters remained within the optimal range suitable for milkfish cultivation. This conclusion is supported by previous studies on the ideal conditions for milkfish farming.

Discussion. Based on the results of this study, the best performance in terms of WG, TFC, FUE, FCR, SGR, and SR was observed in the treatment B, with values of 94.24±0.36 g, 236.84±3.27 g, 39.78±4.00%, 1.94±0.15% day^{-1}, and 96.67±5.77%, respectively.

The addition of oil derived from the BSF larvae in feed has a significant effect on the WG of milkfish. Sandeep et al (2022) reported that fish fed diets supplemented with specific concentrations of larval oil exhibited higher WG compared to the control group without oil. This suggests that BSC larvae oil can improve fish growth efficiency by enhancing nutritional and metabolic intake. The oil may facilitate protein digestion into amino acids, making protein absorption easier for the fish. Optimal protein absorption, in turn, positively influences the increase in fish biomass. Similarly, Sypniewski et al (2020) found that the inclusion of BSF oil enhances protein and fat availability, supporting better nutrient absorption and consequently higher WG and biomass. However, optimal inclusion levels should be determined for each species to maximize growth benefits while maintaining nutritional balance.

WG is calculated as the difference between final and initial fish weight, while the SGR measures the percentage of growth relative to the initial weight over a given period, providing an indication of growth efficiency. Therefore, higher WG corresponds to higher SGR values. Rawski et al (2020) reported that increases in WG resulting from high-quality feed are reflected in higher SGR, indicating optimal feed utilization. Additionally, fish are able to utilize carbohydrates more effectively for metabolic needs, allowing available protein to be directed more efficiently toward growth.

The variation in TFC among treatments is likely influenced by factors such as fish appetite, individual size differences, and growth rate. This is consistent with the findings of Putra et al (2020), who stated that feed consumption is affected by age, weight, health status, stomach capacity, nutritional content, feed palatability, and water temperature. Additionally, feed aroma and texture play a significant role in determining consumption levels. The treatment B had a more pronounced fishy aroma and a softer texture compared to other feeds, making it more appealing to the fish. High palatability increases feed acceptance, leading to higher total feed consumption. Afriyanti et al (2020) similarly noted that feed intake is influenced by feed quality, including palatability, flavor, and nutritional content. In contrast, the lowest TFC was observed in the treatment F, which may be due to less favorable aroma and texture characteristics. Fish tend to be more attracted to feeds with distinctive and suitable sensory properties, which can enhance consumption and, subsequently, growth. According to Mulyani & Haris (2021), fish palatability is significantly affected by the taste, smell, and texture of the feed. Optimizing these sensory attributes is crucial for maximizing feed intake and promoting better growth. This is supported by Do et al (2022), who reported that diets containing BSF larvae are palatable and do not negatively impact fecal characteristics or blood chemistry in fish.

In addition to feed consumption levels, another important factor affecting fish growth is FUE. Based on the results of this study, the highest FUE was observed in the treatment B. This may be attributed to the presence of linolenic acid in the feed, which is believed to enhance the efficiency of feed utilization in milkfish. Rakhfid et al (2020) reported that fish fed with appropriate levels of linolenic fatty acids demonstrated improved growth rates, FUE, and FCR. A high FUE value indicates that the feed provided has good nutritional quality, allowing it to be efficiently used by fish to support both metabolic activity and growth. This is supported by Astino et al (2021), who stated that an increase in FUE reflects the quality of the feed, enabling more effective nutrient absorption and conversion into biomass. According to Anggraini et al (2018), several factors influence FUE, including the quantity of feed provided, where overfeeding can lead to waste and deteriorated water quality, while underfeeding can limit growth potential. Other influencing factors include stocking density (as overcrowding may induce stress and impair metabolism), individual fish weight, age, water temperature, and feeding methods (including feed quality, placement, and feeding frequency). According to Isnawati et al (2015) and Abd El-Hack et al (2022), nutrients from the feed consumed are metabolized and absorbed to form new tissue, resulting in growth. From an economic perspective, high feed efficiency contributes to lower feed costs, ultimately reducing overall production expenses. Marwan et al (2022) also noted that the digestibility of feed is directly proportional to its utilization efficiency; thus, feeds with higher digestibility result in greater efficiency in nutrient use.

Addition of BSF larvae oil in feed at different doses resulted in varying FCR values. Based on the study results, the treatment B produced an FCR value of 2.38. This suggests that the feed had good nutritional quality and met the dietary needs of the fish, allowing for efficient utilization that supported optimal growth. Marwan et al (2022) also indicated that a 1.5 mL addition of BSF larvae oil in feed positively influenced FCR, highlighting that feed conversion is directly linked to how efficiently fish can use feed for growth. FCR is closely related to feed quality; a lower FCR indicates better-quality feed and more efficient conversion of feed into biomass. When feed is easily digested, the nutrients, especially proteins, can be absorbed and used effectively to support tissue maintenance and growth. Protein plays a critical role in determining feed quality and, consequently, FCR values. According to Marwan et al (2022), feeds formulated with appropriate ingredients and protein levels aligned with fish nutritional requirements enhance digestibility, which in turn promotes growth. Additionally, FCR is influenced by fish mortality rates. Mengistu et al (2020) noted that FCR is affected by mortality, individual variability in feed-to-biomass conversion, and environmental conditions in aquaculture systems. In this study, the highest FCR value did not exceed 3. Based on these findings, it can be concluded that the FCR values observed in milkfish were within an acceptable and efficient range. This is supported by Anggraini et al (2018), who stated that a good feed conversion value is less than 3. The lower the FCR, the higher the feed quality, and the greater the resulting growth performance.

The SR represents the ratio of the number of fish surviving at the end of the cultivation period to the number at the beginning. In this study, BSF larvae oil addition in artificial feed had a notable effect on the survival of milkfish. The highest SR was observed in the treatment B, with a value of 96.67±5.77%, although this was not significantly different from the other treatments. Several factors influence fish survival, including feed quality and water quality. Rakhfid et al (2020) emphasized that both external factors, such as the quantity and quality of feed, as well as water conditions, play important roles in determining survival rates. Nutritional adequacy is also crucial: feed that meets the physiological needs of milkfish supports cellular repair and enhances resistance to disease. Notably, BSF larvae oil contains lauric acid, which functions as an antioxidant capable of preventing and repairing cellular damage in fish (Cardoso et al 2020). Additionally, BSF larvae oil is rich in eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), essential fatty acids that support growth and strengthen immune response. Li et al (2016) reported that the presence of EPA and DHA in BSF larvae oil contributes to survival rates of 96-100%. Compared to traditional fish oil, BSF larvae oil offers an advantage due to its high lauric acid content (up to 44.9%) which is absent in conventional fish oil (Bakar et al 2021). These nutritional properties make BSF larvae oil a promising alternative lipid source in aquaculture feed formulations. Another important factor influencing fish survival is the quality of water in the cultivation environment. Unsuitable water conditions can lead to stress in fish, reduced appetite, and, in severe cases, death. Mulqan et al (2017) stated that SR in fish is influenced by various water quality parameters, including dissolved oxygen, ammonia, temperature, and pH, as well as feed quality, fish age, environmental conditions, and overall fish health. Based on the results of this study, the SR of milkfish can be classified as good. According to Marwan et al (2022), milkfish SR can reach 80-90% under optimal water quality conditions. The high SR observed in this study indicates that the cultivation process was successful.

Water quality observations included measurements of temperature (°C), pH, salinity (ppt), and dissolved oxygen (mg L^{-1}). These parameters were measured daily in the morning and evening using water quality monitoring instruments. Water quality measurements taken during the maintenance period show that the average values for temperature, pH, salinity, and dissolved oxygen remained within the optimal range. Specifically, water temperatures ranged from 26.30 to 28.50°C, which falls within the ideal range for milkfish cultivation. Cardoso et al (2020) reported that the optimal temperature for milkfish growth and survival is 24-31°C, while the broader ideal range for milkfish culture is 23-32°C. Water temperature plays a critical role in fish physiology, as it directly affects metabolic processes and growth rates. Inappropriate temperatures can hinder metabolic efficiency, resulting in reduced growth. Knight et al (2021) emphasized that, because fish are ectothermic, their metabolic rate and digestion are highly influenced by water temperature, and optimal temperatures enhance feed utilization. Similarly, Rakhfid et al (2020) noted that water temperature affects the metabolic activity, survival, and growth of aquatic organisms. Moreover, temperature indirectly influences aquatic life through its effect on the solubility of dissolved oxygen in water.

During the study, the dissolved oxygen levels in aquaculture media ranged from 3.53 to 5.96 mg L^{-1}, which is within the optimal range for milkfish cultivation. The salinity of the water during cultivation ranged from 26 to 27 ppt. According to Herawati et al (2020), milkfish exhibit good growth at salinity levels between 15 and 35 ppt, and dissolved oxygen concentrations above 3 mg L^{-1} are considered sufficient. Insufficient dissolved oxygen in aquaculture systems can hinder fish activity, slow growth, and may even lead to mortality. This is supported by Wicaksono et al (2018), which stated that oxygen is a limiting factor in aquaculture, when its availability is inadequate, all biological activities of the cultured species are negatively affected. Fish require oxygen to support respiration and to metabolize feed into energy for essential functions such as swimming, growth, and reproduction. Therefore, inadequate levels of dissolved oxygen can disrupt these processes and may result in reduced growth rates or death.

The pH values recorded during the study ranged from 7.9 to 8.2, which also falls within the optimal threshold for milkfish cultivation. According to the Indonesian National Standard (SNI 6148.3:2013), the ideal pH range for milkfish culture is 7.0 to 8.5. Similarly, Cardoso et al (2020) reported that milkfish thrive in pH conditions ranging from 8 to 9, as these levels are conducive to growth and reproduction. If the pH deviates significantly from the optimal range, it can impair metabolic processes in fish. Rosmina et al (2021) emphasized that both water temperature and pH are critical limiting factors that influence and determine the speed of metabolic reactions in the body of milkfish.

Conclusions. The results of this study demonstrate that BSF larvae oil (from *Hermetia illucens*) addition in feed had a significant effect ($p < 0.05$) on the weight gain, total feed consumption (TFC), feed conversion ratio (FCR), and specific growth rate (SGR) of milkfish (*Chanos chanos*). The optimal dose was observed in treatment B (1.5 mL BSF larvae oil addition), produced a weight gain of 94.24±0.36 g, TFC of 236.84±3.27 g, FCR of 2.38±0.01, FUE of 39.78±4.00%, SGR of 1.94±0.15% day^{-1}, and SR of 96.67±5.77%. BSF larvae oil is rich in beneficial fatty acids, indicating its potential as a sustainable alternative to fish oil for enhancing the growth performance of milkfish. Given its nutritional profile and favorable outcomes, BSF larvae oil addition presents a promising solution for reducing reliance on fish oil in aquaculture feeds formulations. These findings support the broader application of BSF larvae oil not only in milkfish farming but also as a viable feed ingredient for other commercially important aquaculture species.

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Conflict of interest. The authors declare that there is no conflict of interest.

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