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Research Article

Black Soldier Fly (*Hermetia illucens*) Oil Inclusion and its Effects on Growth Performances in Common Carp (*Cyprinus carpio*)

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Abstract

The demand for common carp (*Cyprinus carpio*) either its seed or consumption measures has increased every year. Fish growth can be increased by adding nutrients in the form of animal oil sources. An alternative ingredient that can be used to support fish growth with good nutritional content and relatively inexpensive is maggot oil or black soldier fly (*H. illucens*) oil. The purpose of this study was to determine the effect of maggot oil (*H. illucens*) in artificial feed on the growth performance of common carp and to determine the best dose of maggot oil. This study used a complete randomized design (CRD) with four treatments and three replicates: A, B, C, and D with the addition of maggot oil doses of 0%, 10%, 15%, and 20%, respectively. The test fish used was a common carp fry measuring 3.59±0.06 cm, 0.79±0.05 g. Observation time was 30 days with a stocking density of 15 fish/aquarium. The results showed that the addition of maggot oil (*H. illucens*) had a significant effect (P<0.05) on TFC, FCR, FUE, SGR, and survival. Based on the results of the study, the best dose was obtained in the addition of 15% maggot oil with value of TFC 10.57±0.26 g, FCR 1.52±0.03, FUE 65.43±1.54%, SGR 1.57±0.04%/day, and SR 95.56±3.85%. For further research, it is possible to use magot oil to increase carp production.

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1. Introduction

Common carp (*Cyprinus carpio*) is a type of fish that lives in freshwater with the family Cyprinidae and belongs to the omnivorous fish group which means all-eater (Zhou *et al*., 2017). The demand for common carp from fry stadia to consumption measures has increased every year. Carp production in Indonesia has increased by 8.98% in 2020 (536,349 tons) and in 2021 (584,496 tons) (Bakar *et al*., 2021; KKP, 2022). Efforts to increase fish production to meet market demand are always sought. One of the efforts to increase carp production is by giving high-quality feed since feed is one of the most important aspects of fish farming.

Fish growth can be improved by providing quality feed following the nutritional needs of carp. The feed used for carp is in the form of artificial feed with a nutrient content of 30% - 35% of protein and fat 5% - 15% (Takeuchi *et al*., 2002; Wang *et al*., 2019). Quality feed can be improved by adding nutrients in the form of animal oil sources in artificial feed. Oil, as lipid group, is the main food for living organisms acting as a source of high energy for fish growth and activity (Purnama *et al*., 2021; Kim *et al*., 2021). Fat plays an important role for fish because essential fatty acids are needed for the body (Tocher, 2015; Nguyen *et al*., 2021). Essential fatty acids such as linolenic and linoleic acids can help to promote fish growth and development. Fish cannot synthesize essential fatty acids so if it lacks essential fats, it can cause visual and nervous disorders and can inhibit fish growth (Belghit *et al*., 2019; Siahaya, 2020). One of the local raw materials in the form of oil that can be used as nutrients in feed is maggot oil.

Maggot oil or Black Soldier Oil (BSO) (*Hermetia illucens*) is one of the sources of lipids from black soldier fly larvae (BSF) which have a good nutrition for fish. Maggots contain nutritional content in the form of protein of 42% and fat of 35% and have a linoleic fatty acid profile content with a concentration of 3.6% - 4.5% and linolenic fatty acids of 0.08% -0.74% (Li *et al*., 2016; Tawwab *et al*., 2020). Maggot oil is considered capable of promoting growth effectively. Research on the use of maggot oil had been carried out on juvenile Jian carp by Li *et al*. (2016) who stated that the use of maggot oil at a dose of 25% can increase SGR by 3.30%. Moreover, Bakar *et al*. (2021) stated that the use of maggot oil at a dose of 25% can increase the highest SGR of tilapia by 2.27%. However, research on the use of maggot oil has never been conducted on common carp fry. Therefore, to improve the quality and quantity of common carp, it is necessary to make efforts to utilize maggot oil added to artificial feed for the growth performance of common carp (*C. carpio*) fry. The purpose of this study is to determine the effect of maggot oil (*H. illucens*) in artificial feed on the growth performance of common carp (*C. carpio)* and to determine the best dose of maggot oil (*H. illucens*).

2. Materials and Methods

This research was conducted at the Mijen fish seed center (BBI), Semarang City, Central Java. The test materials used in this study consisted of experimental animals and feed.

2.1 Material

The experimental animal used in this study was carp fry with a size of 3-4 cm from the Balai Benih Ikan Center (BBI), Mijen, Semarang, Central Java. The stocking density for observation was 15 fish per bucket. According to Herawati *et al*. (2020a), common carp measuring 3.59±0.06 cm, 0.79±0.05 g are stocked with a stocking density of 1 fish/liter. The container used in this study was a plastic bucket with a capacity of 30 L. The water capacity used was 15 liters/container. The number of buckets used was 12 pieces equipped with aeration. The tools used during the research process were hoses functioning for aeration and siphon, aerators functioning as oxygen producers, and a net used for bucket covers to avoid fish from jumping out.

This research is an addition, not a substitution or substitute for fish oil or palm oil. The purpose of adding maggot oil is because the lauric acid found in maggot oil is not found in fish oil and palm oil. Palm oil can affect protein content, increase immunity, growth, feed efficiency, survival, and reproductive success (Samsi and Asthutiirundu, 2022). Fish oil contains Eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3) which function for growth and increase immunity (Sasongko *et al*., 2022). Maggot oil (*H. illucens*) contains 40.1% of lauric acid (C12:0), 13.1% of palmitic acid (C16:0), 9.88% of myristic acid (C14:0), 3.6%-4.5% of linoleic acid (18:2n-6), and 0.08% - 0.74% of linolenic acid (18:3n-3) (Fawole *et al*., 2021; Li *et al*., 2016). The lauric acid found in maggot oil is not found in fish oil and palm oil (Fawole *et al*., 2021). The high lauric acid in maggot oil functions as an antioxidant, combats various types of pathogens, as an anti-microbial, and increases HDL (high-density lipoprotein) so as to minimize narrowing of blood vessels due to fat (Sandhya *et al*., 2016).

2.2 Method

The test feed for common carp is in the form of artificial feed added with maggot oil. Feeding was carried out three times a day using the fixed feeding rate method of as much as 5% of the biomass weight and was observed for 30 days. The feed used was artificial feed with the formulation (Table 1).

2.2.1 Total Feed Consumption (TFC)

According to Pereira *et al.* (2007), the calculation of the total feed consumption can be calculated using the formula as follows:

$$TFC = F1 - F2 \quad \text{.......... (Eq. 1)}$$

where:

TFC : Total Feed Consumption
F1 : The amount of starting feed (g)
F2 : Amount of residual feed (g)

2.2.2 Feed Conversion Ratio (FCR)

According to Tacon (1993), the calculation of the feed conversion ratio or Feed Conversion Ratio (FCR) is as follows:

$$FCR = \frac{F}{(Wt+D)-Wo} \quad \text{........ (Eq. 2)}$$

where:

FCR : Feed Conversion Rate
F : The amount of feed consumed (g)
Wt : Weight of biomass at the end of the study (g)
Wo : Weight of biomass at the beginning of the study (g)
D : The weight of the biomass of dead fish (g).

Table 1. Arrangement of feed formulations (% weight dry)

Types of Feed Ingredients	Feed Composition (g/100 feed)			
	A (0%)	B (10%)	C (15%)	D (20%)
Fish Meal	25	25	25	25
Soy Flour	33	33	33	33
Cornstarch	3	3	3	3
Rice Bran Flour	15.5	15.5	15.5	15.5
Flour	14	14	14	14
Fish Oil	3	3	3	3
Palm Oil	3	3	3	3
Vitamin-mineral Mix	2.5	2.5	2.5	2.5
CMC	1	1	1	1
TOTAL	**100**	**100**	**100**	**100**
Maggot Oil (BSO)	-	0.765	1.15	1.53
Protein (%)*	40.13	42.74	44.94	38.21
BETN (%)*	16.18	15.59	11.34	18.6
Fat (%)*	19.45	20.33	23.28	17.97
Energy (kkal)	338.45	353.24	274.21	325.79
Ratio E/P	8.43	8.26	8.33	8.53

Note: The composition of feed formulations is in accordance with the research of Herawati *et al.* (2020); calculated based on Digestible Energy according to Wilson (1982) for 1 g of protein is 3.5 kcal/g, 1 g of carbohydrates is 2.5 kcal/g and 1 g of fat is 8.1 kcal/g. According to De Silva (1987), the E/P value for optimal growth of fish ranges from 8-12 kcal/g. Maggot oil dose modifies from the research of Bakar *et al.* (2021); Saraswanti Indo Genetech Laboratory, Bogor, West Java, Indonesia (2022).

2.2.3 Feed Utilization Efficiency (FUE)

According to Tacon (1987), the calculation of feed efficiency is obtained from the comparison between the weight gain of fish and the amount of feed consumed. The efficiency of feed utilization can be calculated using the following equation:

$$FUE = \frac{Wt - Wo}{F} \times 100\% \quad \text{........ (Eq. 3)}$$

where:

FUE : Feed Utilization Efficiency (%)
Wt : Weight of biomass at the end of the study (g)
Wo : Weight of biomass at the beginning of the study (g)
F : The amount of feed consumed during the study (g)

2.2.4 Specific growth rate (SGR)

According to Fagbenro *et al.* (1992), the calculation of a specific growth rate can be calculated using the formula as follows:

$$SGR = \frac{Ln\,Wt - Ln\,Wo}{t} \times 100\% \quad \text{..... (Eq. 4)}$$

where:

SGR : Specific Growth Rate (%/day)
Wt : Weight of biomass at the end of the study (g)
Wo : Weight of biomass at the beginning of the study (g)
t : Maintenance time (days)

2.2.5 Survival Rate (SR)

The survival rate of common carp can be calculated using the formula from Devic *et al.* (2017), which is as follows:

$$SR = \frac{Nt}{No} \times 100\% \quad \text{.......... (Eq. 5)}$$

where:

SR : Survival Rate (%)
No : The number of fish at the beginning of rearing (fish)
Nt : The number of fish at the end of maintenance (fish)

2.2.6 Water quality

Water quality measurements in the study include temperature (°C) using a mercury thermometer, acidity (pH) using a pH meter, dissolved oxygen (DO) using a DO meter and ammonia.

2.2.7 Experimental design

This study used a complete randomized design (CRD) with four treatments and three replications. The treatments tested were treatments A, B, C, and D with the addition of maggot oil doses of 0%, 10%, 15%, and 20%/100 g of feed, respectively.

Treatment A: Feed-added maggot oil at a dose of 0%
Treatment B: Feed-added maggot oil at a dose of 10%
Treatment C: Feed-added maggot oil at a dose of 15%
Treatment D: Feed-added maggot oil at a dose of 20%

2.3 Analysis Data

The obtained data was analyzed using analysis of variance (ANOVA), after performing a normality, uniformity, and an additivity test to ensure the data was normal, homogeneous, and additive. Assuming a known significance ($P < 0.05$), then proceeded to Duncan's multi-region test to determine the mean difference between treatments and the best treatment. On the other hand, water quality data were analyzed descriptively.

3. Results and Discussion

3.1 Result

3.1.1 Specific growth rate (SGR)

The result of the highest specific growth rate (SGR) value on the addition of maggot oil was the C treatment (maggot oil 15%) of 1.57±0.04%/day and the lowest value in the addition of maggot oil of 20% (D) was 0.86±0.08%/day (Figure 1). The difference in results is 0.71%/day. The results showed that treatments A and D did not differ, while treatment C differed from treatments A, B, and C. Polynomial orthogonal assays can be used to determine the optimum dose at a specific growth rate.

3.1.2 Total Feed Consumption (TFC)

Total feed consumption (TFC) is the amount of feed consumed by common carp (*C. carpio*) during the study. Based on the graph of the total feed consumption, it showed that treatment A was not significantly different from treatment D, but significantly different from treatments B and C (Figure 2). The total yield of feed consumption with the addition of maggot oil in artificial feed by 15% (C) in common carp gave the highest treatment of 10.57±0.26 g.

3.1.3 Feed Conversion Ratio (FCR)

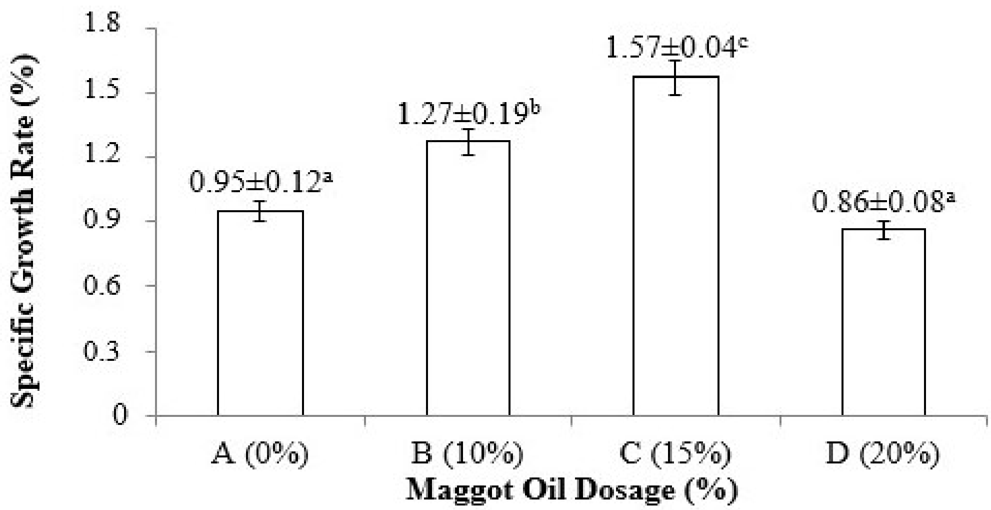

Figure 1. The value of the specific growth rate of Common carp (*C. carpio*)

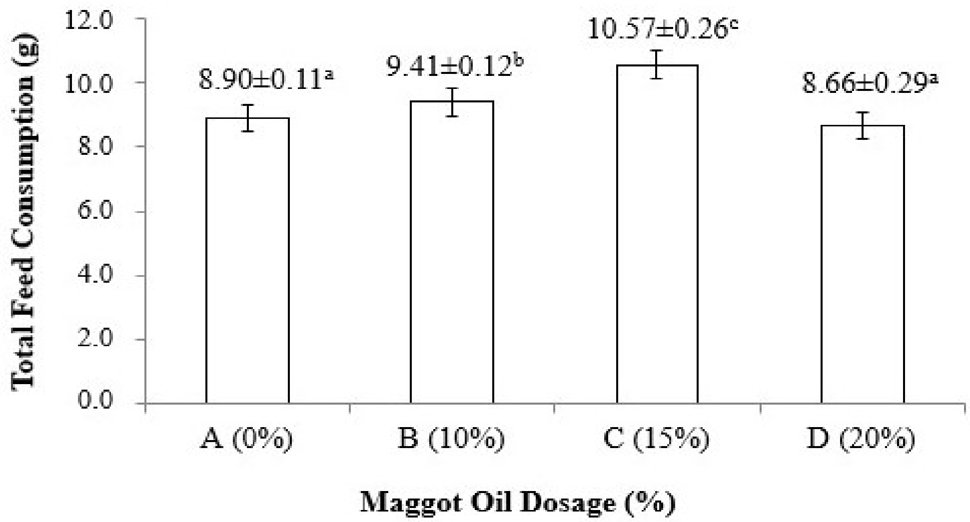

Figure 2. The total value of carp feed consumption (*C. carpio*)

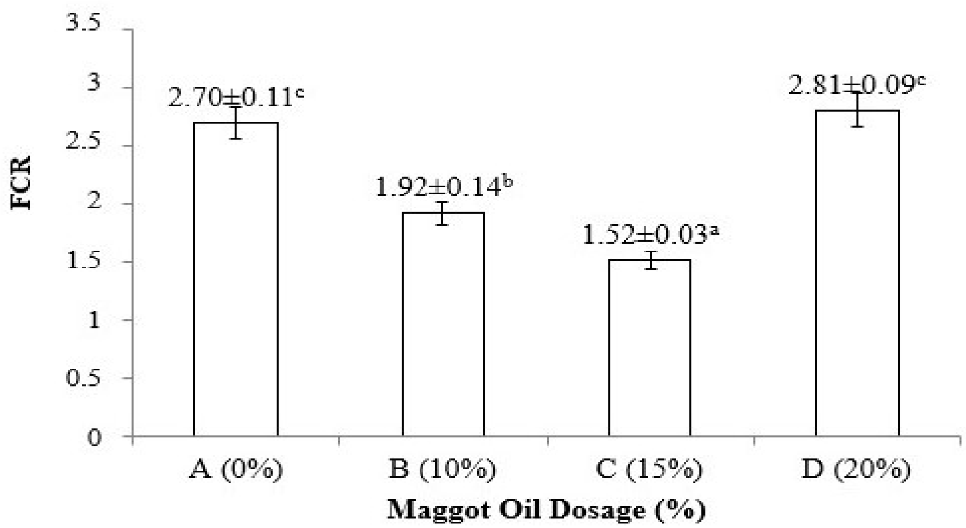

Figure 3. The value of the conversion feed ratio of common carp (*C. carpio*)

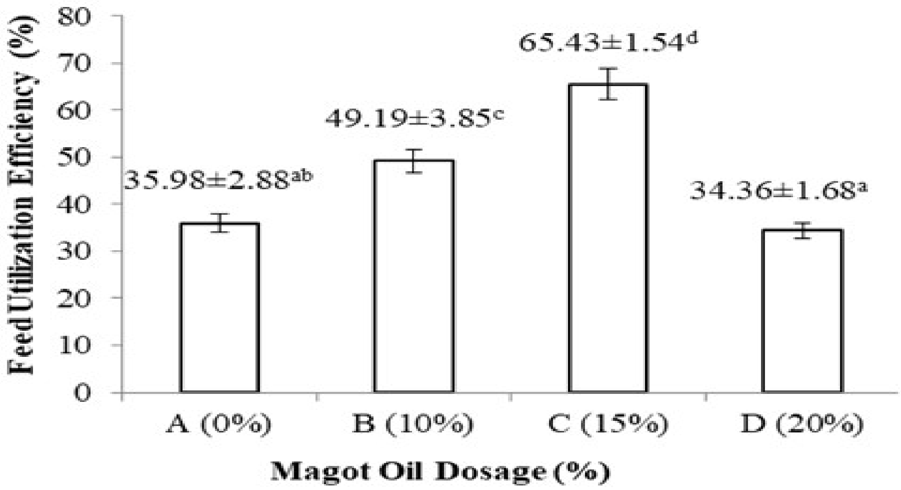

Figure 4. Feed utilization efficiency value (*C. carpio*)

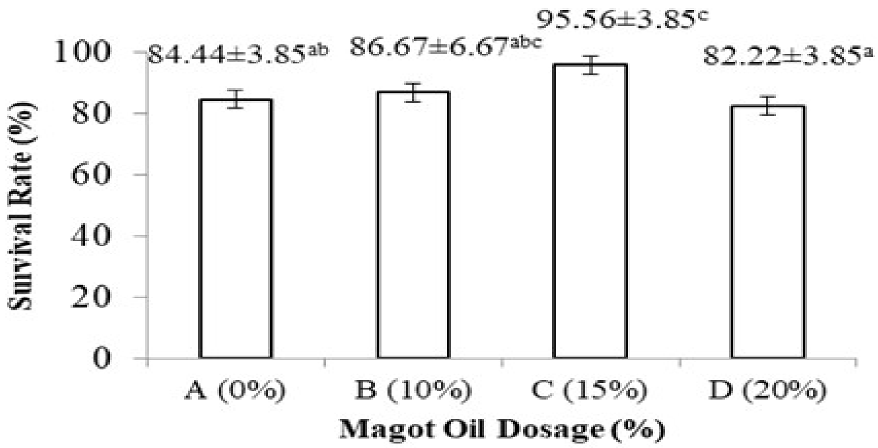

Figure 5. The value of the survival rate of common carp (*C. carpio*)

The graph showed that treatment C differed from treatments A, B, and D. Treatment A did not differ from treatment D but differed from treatments B and C. The result of the highest feed conversion ratio (FCR) value in the addition of maggot oil was in treatment D of 2.81±0.09 and the lowest was in treatment C of 1.52±0.03. The difference in the result of the FCR value is 1.29 (Figure 3).

3.1.4 Feed Utilization Efficiency (FUE)

Based on the study results, data on the efficiency value of feed utilization in common carp (*C. carpio*) was obtained. The graph showed that treatment C differed from treatments A, B, and D. Treatment A did not differ from treatment D. The highest Feed Utilization Efficiency (FUE) value in the addition of maggot oil was in C treatment of 65.43 ±1.54% and the lowest was in the D treatment of 34.36±1.68% and the difference from the result was 31.07 % (Figure 4).

3.1.5 Survival rate

The survival rate of fish means the ability of carp to survive during the maintenance process. Data on the survival rate of common carp (*C. carpio*) which was conducted for 30 days of maintenance were obtained. It showed that treatment A did not differ from treatments B and D, but was significantly different from treatment C. The result of the highest carp survival rate value on the addition of maggot oil was in C treatment of 95.56 ± 3.85%. The lowest value with the addition of maggot oil 1.53 ml (D) was 82.22±3.85% (Figure 5).

3.1.6 Water quality

Water quality is a supporting factor for the success of aquaculture activities. The parameters of water quality include temperature, dissolved oxygen (DO), pH, and Ammonia (NH_3). The results of measuring water quality in carp maintenance media (*C. carpio*) during the research were suitable (Table 2).

3.2 Discussion

Growth is an increase in size and volume in the body. In common carp, the growth happens due to the presence of nutrients entering the body and can be utilized optimally. Based on the result of this research, the addition of maggot oil had a significant effect on total feed consumption (TFC), feed conversion ratio (FCR), feed utilization efficiency (FUP), and specific growth rate (SGR). The best results were in treatment C, seen from the results of TFC, FCR, FUE, and SGR, namely 10.57±0.26 g, 1.52±0.03, 65.43±1.54%, and 1.57% / day, respectively. The addition of maggot oil at a dose of 15% (treatment C) is assumed to be better than other treatments. This is due to the fatty acid on maggot oil. Li *et al.,* (2016) stated that maggot oil has a content of linoleic fatty acids (18:2n-6) with a concentration of 3.6% - 4.5% and linolenic fatty acids (18:3n-3) of 0.08% - 0.74%. Maggot oil contains the essential fatty acids linoleate and linolenic needed by fish for growth and development (Fawole *et al*., 2021). Judging from the nutrients in the feed, treatment C has the best protein content compared to other feeds, which is 44.94% and fat content is 23.28%. The protein and fat needs for carp fry are 30-35% and by 5-15%, respectively (Takeuchi *et al*., 2002). Linolenic substrate is the basis formation of long-chain linoleic fatty acid linoleic acid for the formation of long-chain EPA and DHA. EPA and DHA in metabolism are used for energy and support growth (Xu *et al*., 2020). EPA and DHA help to form proteins and amino acids as a source of energy and replace damaged cells to increase growth (Dugassa and Gaetan, 2018).

the quality of the feed such as palatability, feed tasty power, and nutritional content of the feed. The feed consumed by fish is related to the content of nutrients, raw materials, nutritional digestibility, and physical characteristics of the feed (Manganang and Mose, 2019). Fish growth is also influenced by heredity, age, resistance to disease, and the ability of fish to utilize food and aquatic factors (Napisah and Machrizat, 2021).

The results of the specific growth rate (SGR) showed that the treatment with the addition of maggot oil at a dose of 15% in artificial feed (treatment C) was the best result of this study. The addition of suitable maggot oil in the artificial feed was found to have a good effect as it is in accordance with the nutritional needs of carp. The content of lipid components of maggot oil plays a functional role to meet the needs of the fish body for growth (Danieli *et al*., 2019). The growth rate of carp in the study gave different results. One of the differences in fish growth rates is influenced by feed (Herawati *et al*., 2017). The protein content in butane feed and fat can also affect the cultivar. This is reinforced by Isnawati *et al*. (2015), who stated that the growth of high fish is influenced by the content of protein and fat in the body which functions to build cells, muscles, and tissues as well as a source of energy. The specific growth rate is also influenced by the number of fish consuming feed and gastric capacity. This is reinforced by Brett (1971), that the amount of feed consumed by fish can affect the potential of fish to grow optimally and the daily consumption rate of fish is related to the capacity/ emptying of the stomach.

Table 2. Water quality parameters

No	Variable	Unit	Result		Feasibility
			Morning	Afternoon	
1	Suhu	^{0}C	24-27	24-28	23 – 30[a]
2	DO	-	4.04 – 4.32		>4[b]
3	pH	mg/L	6.8 - 7.8		6.5 – 8.5[c]
4	NH_3	mg/L	0.041 - 0.160		< 0.2[c]

Note: [a]Yaqoob (2021); [b]Homoki *et al*. (2021); [c]Fauzi *et al*. (2020).

The high amount of feed consumption in treatment C tends to produce higher growth as well because it has a fishier scent and softer texture than other feeds that can attract fish to eat. The high palatability of the feed will cause the feed to be preferred by the fish, so the total consumption of the feed obtained is higher. This is reinforced by Afriyanti *et al*. (2020), who stated that high feed consumption rates can be influenced by

The total feed consumption in this study with the addition of maggot oil in artificial feed was 1.15 ml (treatment C), giving the highest treatment. The addition of Maggot Oil to artificial feed with different doses causes a difference in the total consumption produced due to several factors including fish appetite, different size and growth rate of carp, and fish stomach capacity. This is supported by Putra *et al*. (2020), that the factors influenced the feed consumption are age, fish weight, fish health, stomach capacity, nutrition, feed palatability, and water temperature. Larger common carp will consume more feed than smaller fish (Tobuku, 2022). The addition of maggot oil in artificial feed can increase the intake and nutrients so that it will speed up the feed consumption. Feed consumption in fish is related to gastric capacity, so it is related to digestibility and the rate of gastric emptying; the higher the fish can digest nutrients, the faster the rate of gastric emptying (Hadijah *et al*., 2022).

The value of the feed conversion ratio (FCR) on the addition of 1.15 ml maggot oil in artificial feed (treatment C) gave the lowest value. The FCR values obtained from this study ranged from 1.52 to 2.81. The cause of the value of the feed ratio is appetite and environmental factors. Environmental factors can cause fish appetite to decrease, causing fish to only eat a little, and a lot of wasted feed and low metabolism causes the nutrients absorbed for growth to not work well (Ridwantara *et al*., 2019). The value of the feed conversion ratio or FCR is said to be good if it has a small value. This is in line with Simamora *et al*. (2021), who stated that the smaller the value of the feed conversion ratio, the better the quality of the feed given, but if the value of the feed conversion ratio is high, the feed given is of less quality, the higher the feed conversion value. The result is also influenced by the amount of feed given during cultivation; the less feed given, the more efficiently the feed is used by fish.

The feed need for carp cultivation is generally two times the weight of carp, in other words, the FCR value is equal to 2 which means that 2 kg of feed is needed to produce 1 kg of meat. If the feed conversion value for carp is less than 3, the fish are still able to optimally digest the feed and absorb the nutrients contained in the feed (Wulandari *et al*., 2018). This statement shows that the value of the feed conversion ratio or FCR is said to be good.

The value of the feed utilization efficiency variable (FUE) with the addition of 1.15 ml maggot oil in artificial feed (treatment C) gave the best value. The high-efficiency value of feed utilization indicates that the feed given to carp is more efficient and contains good-quality feed. Good quality feed can be utilized by fish efficiently and can be used to support fish activities and growth. This is supported by Astino *et al*. (2021), who stated that the increased feed utilization efficiency value indicates that the feed has good quality so that the feed can be utilized efficiently by fish. The feed given to fish has macronutrient components such as protein, fat, and carbohydrates. The more fat added to the feed, the greater the source of energy produced for fish activities, while energy from protein sources will be used optimally for growth so that there is a protein-sparing effect. According to Welengane *et al*. (2019), the sparing-protein effect is the ability of fish to optimally utilize protein for growth and balance fats and carbohydrates for metabolic activities. This is in line with Lante (2010), that energy derived from oil or fat is sufficient for energy needs, then energy derived from protein is used to build new tissue so that growth occurs.

Feed is said to be good if the efficiency value of feed utilization is close to 100% (Santika *et al*., 2021). High feed utilization efficiency is influenced by the source of nutrients and the amount of each component of the nutrient source in the feed (Herawati *et al*., 2020b). The addition of maggot oil in feed during the observation of carp can increase the efficiency of feed utilization. The value of the efficiency of feed utilization is influenced by the value of the feed conversion ratio. According to Cardoso *et al*., (2020), tilapia feed conversion is influenced by the protein content in the feed according to the nutritional needs of the fish which can result in more efficient feed being given.

The lowest growth of carp in this study was the addition of 1.53 ml of maggot oil (treatment D). Treatment D resulted in the lowest specific growth rate of 0.86%/day with a total feed consumption value (TFC) of 8.66 ± 0.29 g, a feed conversion ratio value of 2.81 ± 0.09, and a value of utilization efficiency feed (EPP) of 34.36±1.68%. The cause of the low growth value in treatment D was suspected to be several factors such as the fish itself and the feed given. The feed in treatment D had the characteristics of a slightly harder texture, slightly fishy smell, less attractive taste to fish that caused in loss of appetite. The odor in treatment D had a less pungent aroma (slightly fishy smell) presumably due to the addition of high maggot oil. According to Sulatika *et al*. (2019), fish appetite can be influenced by the aroma of the feed given to the fish. This is also reinforced by Putra *et al*. (2020), who stated that the factors influenced the feed consumption including age, fish weight, fish health, stomach capacity, nutrition, feed palatability, and water temperature. Fish growth in treatment D gave the lowest growth also influenced by the content of maggot oil. The more application of maggot oil in the feed will increase visceral fat which can reduce carcass yield, affect fish weight loss, and potentially affect the sense of sight and smell of the product at the end of the study (Bakar *et al*., 2021). Maggot oil that is too high can cause visceral fat deposition, fatty liver, and impaired metabolic processes in fish (Fawole *et al*., 2021).

The addition of 1.15 ml maggot oil (*H. illucens*) in artificial feed for carp (*C. carpio*) was able to show growth compared to the addition of 0 ml maggot oil (treatment A). Based on the total value of feed consumption and the efficiency value of feed utilization in this study, the highest addition of 1.15 ml maggot oil (treatment C) was 10.57 g and 65.43%, respectively. The results of this study are lower than the results of research by Herawati *et al.* (2020a), who found that adding maggot flour to the composition of the feed formulation as much as 37.5% in artificial feed for carp fry can produce a specific growth rate value of 2.83%/day, the total value of feed consumption is 19.46 g, and the efficiency value of feed utilization is 75.66%. Based on the FCR value obtained from this study, which was in the range of 1.52-2.81, is higher than the study of Li *et al.* (2016), who stated the addition of maggot oil as a substitute for soybean oil for Jian carp in feed formulations obtained FCR values ranging from 1.40-1.53. The FCR value is also higher than the research by Bakar *et al.* (2021), that the replacement of fish oil with maggot oil in the feed formulation for tilapia showed FCR values ranging from 1.18 to 1.87. This may be due to the quality of the fish meal and composition of feed ingredients in the manufacture of fish feed as well as feed palatability (Bakar *et al.*, 2021).

The survival rate of fish is the ability to survive during the cultivation process. Survival is closely related to the aquatic environment in aquaculture and the availability of feed. Water quality is an important factor in supporting fish farming. Good water quality will affect the survival of cultured fish. The results of the analysis of variance showed that the addition of Maggot Oil (*H. illucens*) in the artificial feed had a significant effect ($P<0.05$) on the survival of carp (*C. carpio*). The highest survival rate value with the addition of maggot oil of 1.15 ml (treatment C) was 95.56±3.85% and the lowest value with the addition of 1.53 ml of maggot oil (treatment D) was 82.22±3.85%. The survival rate value in the study can be said to be good because it is above 80%. According to Patahiruddin (2020), the factors that affect the survival of fish are age, the availability of feed, the handling of fish, and the condition of the aquatic environment.

Based on the research that has been done, the water temperature in the culture media is around 24-28°C. The temperature in the study was still within the normal range for carp cultivation. This is confirmed by Yaqoob (2021), who stated that carp can still grow well at a temperature of 23–30°C, because carp can tolerate low temperatures. According to Sartika *et al.* (2021), the appropriate temperature for fish growth is around 22-24°C, but the optimum temperature for carp cultivation is 25-30°C. Temperature plays an important role in goldfish cultivation because it affects metabolism, fish appetite, and body resistance to disease. The temperature of the carp is still in a feasible limit condition with a suitable temperature of 14-38°C (Mustofa *et al.*, 2018). Dissolved Oxygen (DO) in the cultivation media is around 4.04 - 4.32. The dissolved oxygen value is in optimal conditions. This was stated by Homoki *et al.* (2021) that the dissolved oxygen content in the waters for carp cultivation was more than 4 mg/L. Oxygen is very important for the survival of cultured fish for respiration, living, and activities such as swimming, growing, and reproducing.

Based on observations during the study, the pH value in carp culture ranged from 6.8 to 7.8. The pH value in this study was still in the normal range. pH (degree of acidity) can affect the rate of metabolic reactions of fish which can also affect the rate of growth. According to Fauzi *et al.* (2020), the optimum acidity (pH) value for carp fry is 6.5–8.5. The degree of acidity (pH) can affect the productivity of water. Neutral and alkali waters tend to be more productive than acidic waters (Alam *et al.*, 2020). The results of the ammonia concentration values in this study were in the range of 0.041-0.160. This is supported by Fauzi *et al.* (2020), who stated that the ammonia content in the waters can affect the growth rate because it can be toxic to aquatic organisms, besides the optimum value of ammonia (NH_3) for carp fry is < 0, 2. Ammonia levels in this study were classified as low caused by regular water changes and supported by a good aeration system.

4. Conclusion

The addition of Maggot Oil (*H. illucens*) in artificial feed for common carp has a significant influence ($P<0.05$) on total feed consumption, feed conversion ratio, feed utilization efficiency, specific growth rate, and survival of common carp (*C. carpio*). The best dose of maggot oil added in artificial feed is 15% or 1.15 ml/100 g of feed is capable of producing total feed consumption of 10.57±0.26 g, feed conversion ratio of 1.52±0.03, feed utilization efficiency of 65.43±1.54%, specific growth rate of 1.57±0.04%/day, and survival rate of 95.56±3.85%.

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Authors' Contributions

The contribution of each author as follow, VEH; conceptualized and wrote the original draft. HTJ; performed the research and analysis. TE; provided visualization and supervised the research. SPP; contributed to the data and analysis tool. SW; designed the research, reviewed, and edited the manuscript. All authors discussed the results and contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

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