Original article
DOI: 10.19027/jai.24.2.233-243

Utilization of skipjack tuna *Katsuwonus pelamis* offal waste for mass culture of *Daphnia* sp. as feed for *Betta* sp.

Pemanfaatan limbah jeroan cakalang *Katsuwonus pelamis* untuk kultur massal *Daphnia* sp. sebagai pakan ikan cupang *Betta* sp.

Indra Cahyono[1*], Sri Nurul Mutmainah[2], Buana Basir[2], Ardi Eko Mulyawan[2], Sri Mulyani[3]

[1]Aquatic Resource, Balik Diwa Institute of Maritime Technology and Business Makassar, 90245, Indonesia
[2]Aquaculture, Balik Diwa Institute of Maritime Technology and Business Makassar, 90245, Indonesia
[3]Aquaculture, Faculty of Agriculture, Universitas Bosowa, Makassar 90232, Indonesia
*Corresponding author: indracahyono@itbm.ac.id

(Received December 19, 2024; Revised February 6, 2024; Accepted May 22, 2025)

ABSTRACT

This study aims to assess the impact of skipjack tuna (*Katsuwonus pelamis*) offal soaking water on the mass culture of *Daphnia* sp. for the growth of Betta fish (*Betta* sp.). This study was conducted for 30 days with treatment of offal 4.5 ml/L (treatment B), 7.5 ml/L (treatment C), 10.5 ml/L (treatment D), and commercial feed without skipjack offal soaking water as control (treatment A). The data variables of this study consisted of growth rate and population density of *Daphnia* sp., which were analyzed using variance analysis. The results showed that the highest population growth rate was found in the treatment of offal soaking water 4.5 ml/L with a value of 11.59% and a density of 260 individuals/liter on the 19th day of rearing. *Daphnia* sp. produced from soaking tuna offal can also be used as a natural food for the growth and development of Betta fish, although its effectiveness is still lower than other organic materials.

Keywords: *Daphnia* sp., growth, mass culture, skipjack offal

ABSTRAK

Penelitian ini bertujuan untuk mengetahui pengaruh air rendaman jeroan ikan cakalang (*Katsuwonus pelamis*) pada kultur massal *Daphnia* sp. terhadap pertumbuhan ikan Betta (*Betta* sp.). Penelitian ini dilakukan selama 30 hari dengan perlakuan air rendaman jeroan ikan cakalang sebanyak 4,5 ml/L (perlakuan B), 7,5 ml/L (perlakuan C), 10,5 ml/L (perlakuan D) dan pakan komersil tanpa air rendaman jeroan ikan cakalang sebagai kontrol (perlakuan A). Data variabel penelitian terdiri dari laju pertumbuhan dan kepadatan populasi *Daphnia* sp. dianalisis menggunakan analisis ragam. Hasil penelitian menunjukkan bahwa laju pertumbuhan populasi tertinggi pada perlakuan menggunakan air rendaman jeroan 4,5 ml/L dengan nilai 11,59% dan dengan kepadatan individu 260 individu/liter pada hari pemeliharaan ke 19. *Daphnia* sp. yang dihasilkan dari perendaman jeroan ikan cakalang juga dapat digunakan sebagai pakan alami untuk pertumbuhan dan perkembangan ikan Betta (*Betta* sp.) walaupun efektivitasnya masih lebih rendah dibandingkan bahan organik lainnya.

Kata kunci: *Daphnia* sp., jeroan cakalang, kultur massal, pertumbuhan

INTRODUCTION

Aquaculture of ornamental fish is one of the most economically profitable activities (Choi *et al.,* 2024; Diatin *et al.,* 2019; Arfah *et al.,* 2023). The selling value of ornamental fish is not only considered in terms of total size and/or weight but is more often based on each fish. The value can reach even higher if it has a beautiful body shape and color (Saekhow *et al.,* 2018). Based on information from the Ministry of Marine Affairs and Fisheries, the export value of Indonesian ornamental fish reached 39.06 million United States dollars (US) throughout 2023. The considerable market opportunity for ornamental fish is indeed really promising.

One of the ornamental fish that is profitable to be used as a business in aquaculture is the Betta fish (*Betta* sp.) (Wiratama *et al.,* 2021). This fish is relatively easy to cultivate but relies on natural feed to make its body shape more attractive and better movement (Sanjaya *et al.,* 2020). *Daphnia* sp. is one type of natural feed widely used in ornamental fish culture (Anshar *et al.,* 2023; Vasina *et al.,* 2020). *Daphnia* sp. is a zooplankton commonly used in freshwater fish hatcheries due to its high nutritional value (Hyman *et al.,* 2021; Rasdi *et al.,* 2020; Wiratama *et al.,* 2021). The nutritional content of *Daphnia* sp. varies depending on age and the food it eats. *Daphnia* sp. contains nutrients such as 4% protein, 0.54% fat, and 0.67% carbohydrates (Herawati *et al.,* 2017).

Daphnia sp. cultivation requires nutrients derived from suspended organic materials and bacteria from fertilizers added to the culture medium (Herman *et al.,* 2018). Fertilization with organic materials is the optimal method to support the growth of the *Daphnia* sp. population and enrich its nutrients. In increasing the population of *Daphnia* sp., some studies use organic materials such as chicken and quail manure, tofu pulp and bran (Herawati *et al.,* 2018; Herawati *et al.,* 2020), organic fertilizer (Abo-Taleb *et al.,* 2021) and even wasterwater (Muir *et al.,* 2024).

Various organic materials for the production of *Daphnia* sp. have been used to find the most effective but at a low cost and easy to find. One of them is utilizing offal waste from the fisheries industry. Fish offal waste is also easy to find by utilizing local traditional markets or by storing fish offal from fish auction sites (TPI). Fish offal waste generally contains various nutrients, including N (nitrogen), P (phosphorus), and K (potassium), which are components of organic fertilizers (Rosadi & Catharina, 2022). One fisheries industry waste that has the potential to be utilized as a source of organic material for growing *Daphnia* sp. is skipjack fish (*Katsuwonus pelamis*) offal waste. This type of waste needs to be utilized promptly due to its perishable nature. In addition, if it accumulates, it will have a negative impact on the land and water environment.

In general, the products processed from skipjack offal waste by the community are food ingredients such as shrimp paste and *Bekasang* (Shalahuddin *et al.,* 2022). In addition, other processed products are non-food ingredients, such as a substitute for fish flour in the production process of fish and livestock feed (Raeesi *et al.,* 2023). However, the use of tuna offal waste as one of the natural organic materials to increase the population of *Daphnia* sp. has never been done before. Therefore, this study aims to determine the impact of skipjack offal soaking water (*K. pelamis*) on *Daphnia* sp. mass culture on the growth of Beta fish (*Betta* sp.).

MATERIALS AND METHODS

This research was conducted from June to July 2021 at the Natural Feed Division Installation and Fish Hatchery of *Bontomansi* Fish Seed Center, Gowa Regency, South Sulawesi. This research design uses a quantitative experimental approach with two test animals, *Daphnia* sp. and *Betta* sp..

Cultivation of *Daphnia* sp. with skipjack offal water

Before being used for the *Daphnia* sp. cultivation, skipjack offal waste was fermented with a composition of 1 kg of skipjack offal waste, 1 kg of brown sugar, 2 liters of coconut water, and added with 8 liters of rice water, which was put in a closed container for 14 days. The result of fermentation of skipjack offal was added to the culture medium of *Daphnia* sp., which is done every day with concentration, treatment A (commercial feed without skipjack offal soaking water) as a control, treatment B (4.5 ml/L), treatment C (7.5 ml/L), treatment D (10.5 ml/L). These doses were repeated three times and the control treatment had a standard water density. The water used is sterile with neutralized chlorine disinfectant with an average temperature of 28°C.

The doses used in this study were to prevent toxic properties that may arise and result in the death of *Daphnia* sp.. It is also the basic dose for the use of *Daphnia* sp. culture media as in some literature that uses other waste media for *Daphnia* culture media. Sampling Density of *Daphnia* sp. cultured with skipjack offal waste is done daily to stabilize the supply and growth of *Daphnia* sp. for *Betta* sp. feed.

Daphnia sp. population density

The population density of *Daphnia* sp. was converted using the formula (Holy & Sari, 2020):

$$a = b \left(\frac{p}{q}\right)$$

Note:

a = Total of *Daphnia* sp. individuals in the culture medium (individuals/liter)
b = Average total amount of *Daphnia* sp. from the repeated measurement (individuals/liter)
p = Culture media volume (liters)
q = Water sample culture media volume (liters)

Rate of *Daphnia* sp. population growth

The population growth rate of *Daphnia* sp. was calculated using the formula by Gazali *et al.* (2023):

$$g = \frac{LnNt - LnN0}{t} \times 100$$

Note:

g = Rate of population growth (%)
No = Individual's total at the start of treatment (individuals)
Nt = Individual's total at the peak of population (individuals)
t = Rearing period (days)

Betta sp. rearing

This study used 12 aquarium containers with a size of 100×45×75 cm^3 that had been filled with 100 liters of water. Each container was filled with 10 *Betta* sp.. The *Daphnia* sp. stocking density per container was 20 individuals per day. *Betta* sp. aged 1 month were reared with two spot small aeration points and fed with 10 *Daphnia* sp. every morning and evening per container. Feeding *Daphnia* sp. as food for *Betta* sp. was carried out for 29 days. Replacing water was done every three days, as much as 30% with a siphon and putting water with the driping technique.

Betta sp. growth

Length growth

The absolute length growth of fish was calculated using the formula from (Asiah *et al.,* 2024; Gazali *et al.,* 2023) as follows:

$$L = Lt - L0$$

Note:

L = Growth in absolute length of *Betta* sp. (cm)
Lt = The length of *Betta* sp. at the last rearing period (cm)
L0 = The length of *Betta* sp. at the start rearing period (cm)

Weight Growth

The absolute weight growth of fish is calculated as follows (Setyono *et al.,* 2024; Sinaga & Mukti, 2021):

$$W = Wt - W0$$

Note:

W = Growth in absolute weight of *Betta* sp. (g)
Wt = The weight of *Betta* sp. at the last rearing period (g)
W0 = The weight of *Betta* sp. at the start rearing period (cm)

Proximate analysis

Proximate analysis will be conducted at the Nutrition and Chemistry Laboratory, Pangkep State Agricultural Polytechnic. Proximate analysis will be tested following the Indonesian National Standard (SNI) work procedure shown in Table 1.

Table 1. Feed Proximate Analysis Work Procedure.

No	Parameter Test	References
1	Protein	SNI 01-2354.4:2006
2	Ash Content	SNI 2354.1:2010
3	Water Content	SNI 2354.2:2005
4	Fat Content	SNI 2354.2: 2010
5	NFE	SNI 01-4086-2006

*NFE: Nitrogen free extract.

Data analysis

Utilization of skipjack offal soaking water as liquid organic fertilizer for *Daphnia* sp. growth was analyzed using analysis of variance (ANOVA). Treatments that had a significant effect (P<0.05) were continued with the W-Tukey's real difference test to determine differences in the impact between treatments.

RESULTS AND DISCUSSION

Result

Density and growth rate of Daphnia sp. population

The population density of *Daphnia* sp. in various media rearing changed as the population increased. These results show the duration of each stage in its growth cycle. The average of *Daphnia* sp. population density data from the results of 30 days of rearing can be seen in Figure 1. According to Figure 1, Treatment B (4.5 ml/L) showed the highest peak amount of *Daphnia* sp. on day 10, which was 260 individuals. It indicates that treatment B, with fermented skipjack offal waste concentration of 4.5 ml/L, provides optimal nutrition for the growth of *Daphnia* sp..

This result was followed by treatment A with 240 individuals and treatment C with 215 individuals. The optimal dose to increase *Daphnia* growth is unclear from these results. Treatments B and C (7.5 ml/L) were not significantly different from the control (Treatment A), although they had a maximum increase of 40 individuals on any specific day. It shows that at a certain point, the population of *Daphnia* sp. experienced optimal growth. Meanwhile, Treatment D (10.5 ml/L) had the lowest peak number of individuals, only 40 individuals on the first day, and showed no significant increase thereafter. These results show that the high concentration (10.5 ml/L) may be toxic to *Daphnia* sp., inhibiting growth or causing mortality.

The average value of the population growth rate of *Daphnia* sp. can be seen in Figure 2. Treatment B (4.5 ml/L) had the highest growth rate (11.59 per day) with a small standard deviation (±0.13), indicating consistent and optimal growth. On the other hand, Treatment C (7.5 ml/L) had a lower growth rate than the control (9.22 vs. 10.61 per day), with a small standard deviation (±0.06). These results indicate that this treatment was ineffective at increasing the *Daphnia* sp. population.

Treatment A (control) had stable growth (10.61 per day) with moderate variability (±0.18). Then, the results of Treatment D (10.5 ml/L) did not support the growth of *Daphnia* sp. at all (0.00 per day with standard deviation = 0.00). From these results, it can be confirmed that this dose is toxic or not very supportive of the survival of *Daphnia* sp. because of the nutritional imbalance. The study showed that between treatments A and B, there were significant differences, indicating that *Daphnia* sp. grew better at 4.5 ml/L than the control. In contrast, Treatment C showed that higher concentrations began to reduce the density of *Daphnia* sp.. Therefore, Treatment C to D showed a tolerance limit before toxic effects occurred.

ANOVA and W-Tukey test for growth rate comparation of Daphnia sp.

The ANOVA test results showed an F-statistic value of 26.17 and a p-value of 1.03×10-101.03×10^{-10}. These results indicate a significant difference between the treatment groups (p<0.05). Based on these results, it is

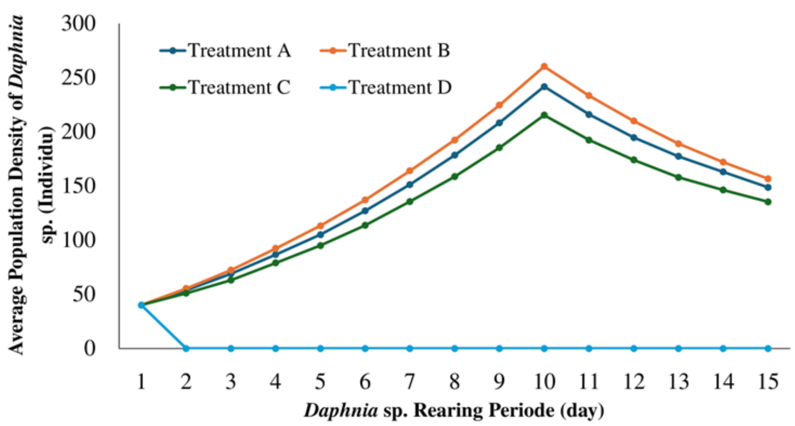

Figure 1. Density population of *Daphnia* sp. in various treatments of skipjack (*Katsuwonus pelamis* L.) offal soaking water.

known that the fermentation treatment of skipjack offal waste significantly affects *Daphnia* sp. growth. The results of the W-Tukey test can bee seen in Figure 3.

These results showed no significant difference in the population growth rate in treatments A and B (p = 0.5904). These results indicate that both treatments have almost the same effect on *Daphnia* sp. growth. It was significantly different in treatment D (10.5 ml/L) compared to all other treatments (p<0.05), where *Daphnia* growth was much lower. This indicates that this treatment caused a significant negative effect due to toxicity.

Length and weight growth of Betta sp.

The results showed that *Betta* sp. fed with *Daphnia* sp., which grew in skipjack offal soaking water during each treatment, experienced an increase in body length. The average length growth of *Betta* sp. can be seen in Figure 4. In addition, the weight of the *Betta* sp. during the study also increased. The average increase in

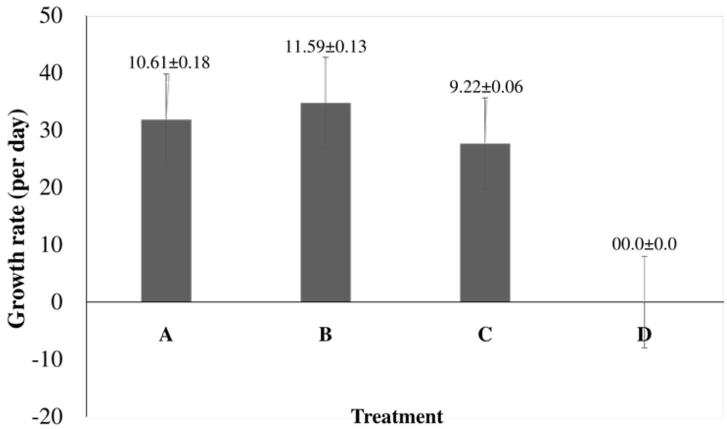

Figure 2. Growth rate of *Daphnia* sp. population in various treatments of skipjack (*Katsuwonus pelamis* L.) offal soaking water.

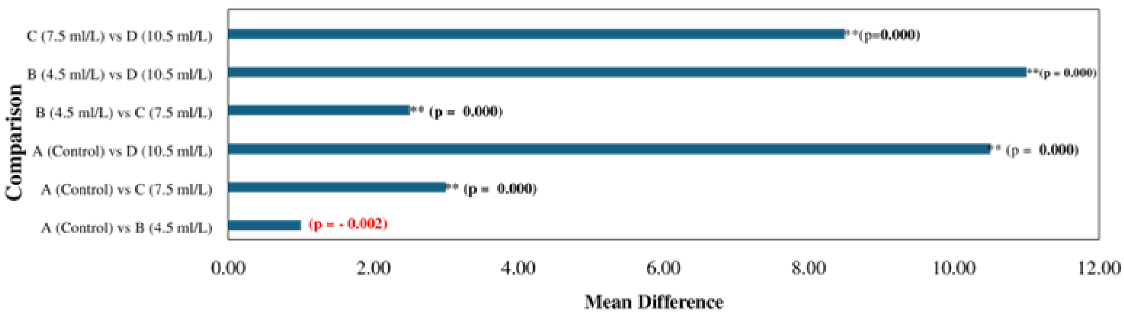

Figure 3. W-Tukey test for growth rate comparison.

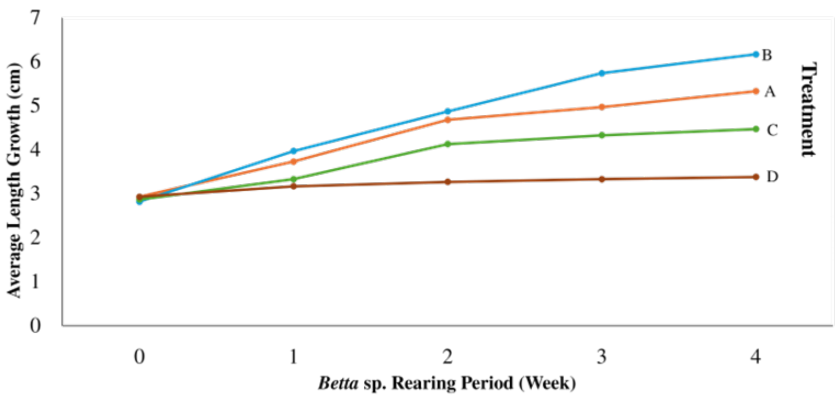

Figure 4. Length growth of *Betta* sp. fed with *Daphnia* sp. treated with skipjack (*Katsuwonus pelamis* L.) offal soaking water.

Betta sp. weight can be seen in Figure 5. The standard deviation of length and weight growth can be seen in Figure 6.

Treatment B (4.5 ml/L) produced the highest length (4.83 grams), indicating the effectiveness of *Daphnia* sp. with the addition of fermented skipjack fish waste at this dose. On the other hand, treatment D (10.5 ml/L) had the lowest growth (2.94 grams) and smallest standard deviation (0.172), indicating similar but poor growth. This probably occurred due to the negative impact of concentrations that were too high. Treatment C (7.5 ml/L) was not significantly different from the control (A), indicating that this dose did not have a better growth effect than the control. The largest variation was found in treatment B (4.5 ml/L) (standard deviation = 1.543), indicating the presence of high and low-growth individuals in this group. The smallest variation was found in treatment D (10.5 ml/L) (standard deviation = 0.172), indicating a homogeneous but not optimal effect on length growth.

Treatment B (4.5 ml/L) had the highest average weight (1.247 grams), indicating that this dose likely provided the best growth with the highest standard deviation (0.722). The weight of *Betta* sp. in this group varied greatly compared to the other treatments. In comparison, treatment D (10.5 ml/L) had the lowest average weight (0.343 grams) with the lowest standard deviation (0.065). These results indicate that the weight of *Betta* sp. in this group is more consistent and similar. These results also indicate that this dose may be too high, so it has a negative impact on *Betta* sp. growth. Treatments A (control) and C (7.5 ml/L) had almost the same weights (0.829 grams and 0.823 grams), indicating that the 7.5 ml/L dose did not have a more significant effect than the

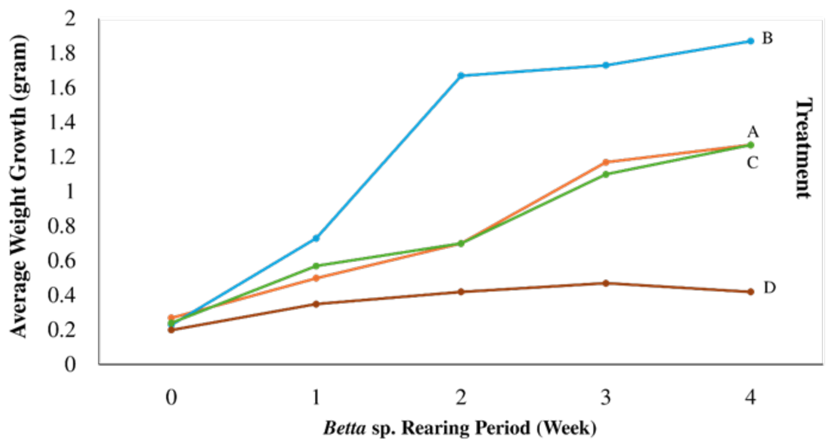

Figure 5. Weight growth of *Betta* sp. fed with *Daphnia* sp. treated with skipjack (*Katsuwonus pelamis* L.) offal soaking water.

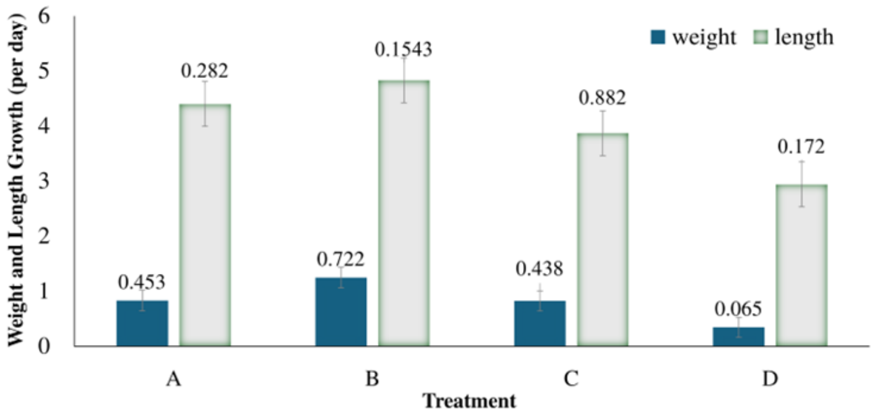

Figure 6. Standard deviation of weight and length growth of *Daphnia* sp.

control (A). The relatively low variation in data from treatment C (0.438) indicates that this dose can also provide more stable results.

Proximate test of skipjack (Katsuwonus pelamis L.) *offal waste*

The results of the proximate test of skipjack offal waste can be seen in Table 2. The protein content is 21.16%. In addition, other organic content is also contained in skipjack offal waste, which can also support the *Daphnia* sp. growth.

Discussion

Population densities and growth rates of Daphnia sp.

In this study, the average density of *Daphnia* sp. can be seen in Figure 1. In treatments A, B, and C, the average density increased from the beginning of the feeding until day 19. The highest increase in individuals was obtained in Treatment B, with a total of 260 individuals. It was followed by Treatment C with 240 individuals and Treatment A with 215 individuals. The same result also occurs when considering the average value of the *Daphnia* sp. population.

The highest number of individuals was found in Treatments A, B, and C proves that skipjack tuna offal waste can be used to increase the *Daphnia* sp. population density. It is due to organic materials needed for the growth of *Daphnia* sp. that contains in skipjack tuna offal waste (Chakma *et al.,* 2022; Zainudin *et al.,* 2024). Organic materials contained in skipjack offal water such as enzymes and amino acids are formed due to bacterial fermentation. The addition of coconut water and rice water as a growing medium provides sufficient nutrients to ensure that the process of fermentation and breakdown of organic matter takes place properly (Cahyono *et al.,* 2021; Safitri *et al.,* 2023; Suartini *et al.,* 2018).

The increased population growth of *Daphnia* sp. in the study because of the skipjack tuna offal contains 4.35% of protein nutrients (Jeerakul *et al.,* 2024) and it can support the *Daphnia* sp. growth. In addition, the utilization of skipjack tuna protein hydrolysate can provide antioxidant peptides that are useful as natural food additives in the formulation of nutritional products. That is potentially increases the nutritional value of zooplankton feed such as *Daphnia* sp. (Rachman *et al.,* 2023). Otherwise, the results show that the dose of skipjack offal water with concentrations above 4.5 ml/L (Treatment B) resulted in a decrease in the *Daphnia* sp. population. The growth of *Betta* sp. that consumed *Daphnia* sp. from treatment D (10.5 ml/L) grew the least. This is because the concentration of Skipjack offal water is too high, causing unbalanced nutrition that leads to the death of *Daphnia* sp.

In terms of the highest total individuals in this study, a value of 260 individuals/liter was obtained. This amount is still below the *Daphnia* sp. given vermicompost fertilizer, reaching 353 individuals/liter (Rasman *et al.,* 2024). The total amount of *Daphnia* sp. in this study was also much lower than in other studies that used African catfish farming waste to cultivate *Daphnia* sp., reaching 2375 tails/liter (Darmawan, 2014). Thus, it can be said that the offal waste of skipjack can be used to accelerate the growth rate of *Daphnia* sp. but is less effective in terms of performance. This condition is possible because the organic matter content of skipjack offal waste is still insufficient compared to other organic materials.

Daphnia sp. growth are strongly influenced by environmental quality, including nutrient availability, toxin levels, and other environmental parameters. The addition of media for the growth of *Daphnia* sp. using fermented skipjack fish waste as much as 4.5 ml/L is the best dose to support the growth of *Daphnia* sp.. However, when the dose is increased to 7.5 ml/L, the growth rate of *Daphnia* decreases due to physiological disturbances, such as decreased food digestion efficiency, reproductive disorders, increased oxidative stress or toxicity of the cultivation environment (Schwarzenberger, 2022). Wibisono *et al*. (2016) state that adding organic waste would increase the abundance of phytoplankton, which is very important for *Daphnia* sp. nutrition. Fish waste contains high levels of organic nutrients, which are beneficial for the growth of *Daphnia* sp. (Alvian *et al.,* 2019).

Furthermore, Turcihan *et al*. (2022) state *Daphnia* sp. growth and survivability are positively affected by nutrient availability, especially when fed with yeast, which increases reproduction, population density, and survival rates. Different diets also affected specific nutrient components, highlighting the importance of nutrient-rich feed for optimal *Daphnia* sp. performance. In this study, it was also seen that *Daphnia* sp. reached the peak of abundance on day 19 and the next day decreased in number until the 29th day of rearing. This growth pattern is similar to that experienced by several studies that have been conducted, which experienced a peak increase in the abundance of

Daphnia sp. and decreased afterward. It occurs because the organic matter used as a source of nutrition has decreased due to the abundant number of organisms that will consume it.

In general, the growth phase of *Daphnia* sp. forms the same population growth pattern and resembles a sigmoid curve consisting of lag phase, log phase (exponential), stationary phase, and death phase (Herawati *et al.,* 2015). Darmawan (2014) states that the peak abundance of *Daphnia* sp. with any culture media is on day 10 depending on the nutrients in the media. Growth acceleration can be faster, but the peak is also between days 9 to 11. After that, the growth of *Daphnia* sp. decreased at the point of decline phase on days 19-22. It is caused by water quality factors, metabolic residues, and overpopulation, which causes harvesting of *Daphnia* sp. for feed, which is usually done at the peak abundance population.

The pattern of zooplankton growth, including *Daphnia*, is similar to that experienced by several studies that have been conducted. The life cycle of plankton always increases at a particular point, which then decreases due to several factors such as environment, food availability, and life cycle. As stated by Herawati *et al*. (2015), the growth phase of *Daphnia* sp. generally patterns the same population growth. It resembles a sigmoid curve consisting of a lag phase, log phase (exponential), stationary phase, and death phase. This situation occurs because the amount of organic matter used as a source of nutrition has been reduced because of the abundance of organisms that will consume it.

Length and weight growth of betta fish (Betta sp.)

Based on Figures 4 and 5, it can be seen that all treatments increased in length and weight growth every week. Treatment B was at the highest-level regarding body length and weight gain. In the second week, treatment B showed a significant weight increase. At the same time, Treatments A and C also showed a significant weight increase, but not as significant as treatment B. On the other hand, treatment D showed a decrease in length and weight growth after three weeks.

This study's results prove that adding *Daphnia* sp. cultured with skipjack offal waste soaking water can increase the length and weight of the body of the Betta fish by increasing its appetite (Wibisono *et al.,* 2024). Although treatment B had high length growth descriptively, its length value was not statistically different from treatments A and C. In addition, treatment B had a value significantly different from treatment D. The same thing also happened to the weight increase of the *Betta* sp.. Treatment B had the highest value, followed by treatments A, C, and D.

In treatment B, *Daphnia* sp. produced more than others, thus increasing the value of the growth rate. With the high growth rate of *Daphnia* sp., the nutrients obtained by *Betta* sp. are sufficient to support the increase in length and weight. The abundance of *Daphnia* sp. as a natural food is beneficial in the metabolism of Betta fish so that their nutritional needs are fulfilled (Matielo *et al.,* 2019). *Daphnia* sp. produced from water immersion of skipjack offal is obtained in large enough quantities and can be used in *Betta* sp. culture. This is because skipjack tuna offal has a relatively high organic matter content including protein, fat, fiber, and calcium (Yan *et al.,* 2024).

This is evident from the skipjack offal proximate test results in this study, which can be seen in Table 2. *Daphnia* sp. is a natural food often used to rearing *Betta* sp. (Matielo *et al.,* 2019). Several studies have found that *Daphnia* sp. is still far below other natural feeds in aquaculture, especially silkworms (*Tubifex* sp.) (Asiah *et al.,* 2024) and mosquito larvae (Abo-Taleb *et al.,* 2021; Mejia-Mejia *et al.,* 2021). Skipjack stomach waste is rich in protein, amino acids, and essential fatty acids, which can increase the availability of nutrients for bacteria or microorganisms in the culture medium. These microorganisms can produce metabolites beneficial to *Daphnia* sp., such as vitamin B12 and bioactive compounds. Fermentation also breaks down complex proteins into simpler peptides and free amino acids, which can improve the *Daphnia* sp. digestive efficiency.

The unsaturated fatty acid content in fish waste can improve feed quality and accelerate *Daphnia* sp. reproduction, ultimately increasing population density. Nutrient imbalance and toxicity occur at higher concentrations in treatments C and D, where nitrogen content (NH_4^+, NO_2-) and fermentation-derived metabolite compounds can become too high, causing osmotic stress and toxicity to *Daphnia* sp. These aquatic organisms are particularly sensitive to free ammonia, which is neurotoxic and can cause impaired osmoregulation as well as gill tissue damage, leading to mass mortality (Hochachka & Somero, 2002). Fermented fish stomach waste can also contain organic nitrogen compounds like indole, skatole, and sulfide. When these compounds are available in high concentrations, they can be toxic to aquatic organisms (Chowdhury *et al.,* 2020).

CONCLUSION

Giving water soaking skipjack offal waste (*Katsuwonus pelamis*) with a concentration of 4.5 ml/L is the optimal treatment for *Daphnia* sp. abundance. The *Daphnia* sp. produced from the offal waste soak skipjack fish can be used to be an alternative natural food for *Betta* sp. and give an impact on its length and weight. Further research can explore the effectiveness of using tuna offal waste to reproduce *Daphnia* sp. as a more economical and sustainable diet for *Betta* sp.. In addition, other parameters can also be tested, such as the survival growth rate (SGR) of *Betta* sp. fed with *Daphnia* sp., which is reproduced with skipjack offal waste soaking water.

ACKNOWLEDGMENT

The authors would like to thank Institut Teknologi dan Bisnis Maritim Balik Diwa for facilitating this research. The authors declare that there is no conflict of interest in this research.

REFERENCES

Abo-Taleb HA, Ashour M, Elokaby MA, Mabrouk MM, El-Feky MMM, Abdelzahe, OF, Gaber A, Alsanie WF, Mansour AT. 2021. Effect of a new feed *Daphnia magna* (Straus, 1820), as a fish meal substitute on growth, feed utilization, histological status, and economic revenue of grey mullet, *Mugil cephalus* (Linnaeus 1758). Sustainability 13: 7093.

Alvian HP, Masithah ED, Azhar MH. 2019. Addition of water from the treatment pond of pangasius fillet waste (*Pangasius* sp.) with different concentrations in the cultivation medium due to the population growth of *Daphnia* sp. IOP Conference Series: Earth and Environmental Science 236: 012004.

Anshar, AR, Relatami, ANR, Amriani, R, Chadijah, A, Rahmi, Tampanggallo, BR, Septiani, RR, Hoven, ID, Agustina KK, Nurdin MA. 2023. The effect of natural (*Daphnia* Sp.) and different synbiotic feed on rainbow celebes (*Marosatherina ladigesi*) growth performance and survival rate. International Journal of Veterinary Science 12: 730–735.

Arfah H, Odang C, Muhamad FD, Fajar M. 2023. Effect of oodev and turmeric powder dietary supplementations on the reproductive performance of sunset platy fish *Xiphophorus maculatus*. Jurnal Akuakultur Indonesia 22: 27–35.

Asiah N, Aryani N, Heltonika B. 2024. Larval rearing of kelabau fish *Osteochilus melanopleurus*, Bleeker 1852 with different live feed. Jurnal Akuakultur Indonesia 23: 262–268.

Cahyono I, Kantun W, Nursyahran, D. 2021. Pengaruh fermentasi limbah jeroan ikan cakalang (*Katsuwonus pelamis*) terhadap kelimpahan fitoplankton dan sintasan larva kepiting (*Scylla serrata*). Agrokompleks 21: 41–47. (In Indonesian).

Chakma S, Rahman MA, Mali SK, Debnath S, Hoque MS, Siddik MAB. 2022. Influence of frozen storage period on the biochemical, nutritional, and microbial quality of Skipjack tuna (*Katsuwonus pelamis*) collected from the Bay of Bengal coast of Bangladesh. Food Chemistry Advances 1: 100139.

Choi SW, Jeong YJ, Jeong YS, Kim K Il. 2024. Genetic and pathogenic characteristics of infectious spleen and kidney necrosis virus isolated from dwarf gourami (*Trichogaster lalius*) imported into Korea. Aquaculture 593: 741297.

Chowdhury DK, Sahu NP, Sardar P, Deo AD, Bedekar MK, Singha KP, Maiti MK. 2021. Feeding turmeric in combination with ginger or garlic enhances the digestive enzyme activities, growth and immunity in *Labeo rohita* fingerlings. Animal Feed Science and Technology. 277: 114694.

Darmawan J. 2014. Population growth of daphnia sp. in a culture media with waste water of African Catfish (*Clarias gariepinus*) intensif culture. Jurnal berita Biologi 13: 57–63.

Diatin I, Suprayudi MA, Budiardi T, Harris E, Widanarni W. 2019. Biofloc technology on the intensive aquaculture of bronze corydoras ornamental fish Corydoras aeneus with different stocking densities. Jurnal Akuakultur Indonesia 18: 202–213.

Gazali M, Effendi I, Wahyuni S, Kurniawan R, Matin A, Syafitri R. 2023. Boosting the growth of tilapia fish using marine macroalgae (*Sargassum* sp.) extracts. AACL Bioflux 16: 1626–1635.

Herawati VE, Hutabarat J, Pinandoyo, Radjasa OK. 2015. Growth and survival rate of tilapia (*Oreochromis niloticus*) larvae fed by *Daphnia magna* cultured with organic fertilizer resulted from probiotic bacteria fermentation. HAYATI

Journal of Biosciences 22: 169–173.

Herawati VE, Nugroho RA, Pinandoyo, Hutabarat J. 2017. Nutritional value content, biomass production and growth performance of *Daphnia magna* cultured with different animal wastes resulted from probiotic bacteria fermentation. IOP Conference Series: Earth and Environmental Science 55: 012004.

Herawati VE, Pinandoyo P, Hutabarat J, Karnaradjasa O. 2018. The effect of nutrient content and production of *Daphnia magna* mass cultured using various wastes processed with different fermentation time. AACL Bioflux 11: 1289–1299.

Herawati VE, Pinandoyo P, Rismaningsih N, Darmanto D, Hutabarat J, Radjasa OK. 2020. The effect of probiotic bacteria in culture media using organic fertilizer for population density, biomass production and nutrient quality of *Phronima* sp. as natural feed. Aquaculture Research 51: 836–843.

Herman H, Andriani Y, Sahidin A, Hidayat T, Herawati T. 2018. Culture of *Daphnia* sp. (crustacean - Cladocera): The effect of manure variation on the growth, natality, and mortality. IOP Conference Series: Earth and Environmental Science 137: 012018.

Hochachka PW, Somero GN. 2002. Biochemical Adaptation: Mechanism and Process in Physiological Evolution. Oxford University Press.

Holy NH, Sari LA. 2020. The effect of catfish and chicken cultivation waste to *Daphnia* sp. culture. IOP Conference Series: Earth and Environmental Science 441: 012057.

Hyman M, Wang Q, Wilson AE, Adhikari S, Higgins BT. 2021. Production of *Daphnia* zooplankton on wastewater-grown algae for sustainable conversion of waste nutrients to fish feed. Journal of Cleaner Production 310: 127501.

Jeerakul C, Kitsanayanyong L, Pansawat N, Boonbumrung S, Klaypradit W, Tepwong P. 2024. Effects of different preparation methods on the physical, chemical and functional properties of protein powders from Skipjack tuna (*Katsuwonus pelamis*) liver. Food Research 8: 64–77.

Matielo MD, Gonçalves Jr. LP, Pereira SL, Selvanci PDC, Mendonca PP, Troina CA. 2019. Five different foods in initial development of Siamese fighting fish (*Betta splendens*). AACL Bioflux 12: 1755–1761.

Mejia-Mejia M, Arce E, García-Rodríguez J, Burciaga LM. 2021. Effect of feeding mosquito larvae on the coloration of siamese fighting fish (*Betta splendens*) during grow-out. International Aquatic Research 13: 71–79.

Muir E, Grossman AR, Chisti Y, Fedrizzi B, Guieysse B, Plouviez M. 2024. Self-aggregation for sustainable harvesting of microalgae. Algal Research 83: 103685.

Rachman SH, Santoso J, Suseno SH. 2023. Antioxidant activity and potential bioactive peptides from skin protein hydrolysate of Yellowfin Tuna (*Thunnus albacares*). Jurnal Ilmiah Perikanan dan Kelautan 15: 248–263.

Raeesi R, Shabanpour B, Pourashouri P. 2023. Use of fish waste to silage preparation and its application in animal nutrition. Online Journal of Animal and Feed Research 13: 79–88.

Rasdi NW, Arshad A, Ikhwanuddin A, Hagiwara A, Yusoff FMd, Azani N. 2020. A review on the improvement of cladocera (Moina) nutrition as live food for aquaculture: Using valuable plankton fisheries resources. Journal of Environmental Biology 41: 1239–1248.

Rasman, R, Patang P, Amirah A. 2024. Population growth of Daphnia sp. with various types of organic fertilizer. Nekton 4: 61–72.

Rosadi NA, Catharina TS. 2022. Effect of fish water waste liquid organic fertilizer on strawberry flowering (*Fragaria* sp.). Jurnal Penelitian Pendidikan IPA 8: 96–100.

Saekhow S, Thongprajukaew K, Phromkunthong W, Sae-khoo H. 2018. Minimal water volume for intensively producing male Siamese fighting fish (Betta splendens Regan, 1910). Fish Physiology and Biochemistry 44: 1075–1085.

Safitri W, Novalina SA, Apriandi A. 2023. Manufacture of local microorganisms (MOL) from fish offal. MARINADE 06: 2654–4415.

Sanjaya Y, Suhara, Nurjhani M, Halimah M. 2020. The influence of *Hermetia illucens* larvae as feed on fitness and the agonistk character of Betta fish (*Betta* sp.). Journal of Entomological Research. 44: 659–664.

Schwarzenberger A. 2022. Negative effects of cyanotoxins and adaptative responses of *Daphnia*. Toxins 14: 770.

Setyono BDH, Aprian F, Marzuki M, Affandi RI. 2024. The effect of immersion time in thyroxine hormone on growth and survival of koi (*Cyprinus carpio*). AACL Bioflux 17: 1186–1197.

Shalahuddin, Nur Utomo M, Cahyaningrum W, Karunia E. 2022. Increased added value of fish wasted in efforts to commercialize competitive products and based information technology. International Journal of Community Service 2: 94–100.

Sinaga VOB, Mukti RC. 2021. The Growth of Tilapia (*Oreochromis niloticus*) with the Addition of Probiotics to Feed in Sakatiga Village, Indralaya District, Ogan Ilir Regency, South Sumatera. Journal of Aquaculture and Fish Health 11: 90–96.

Suartini K, Abram PH, Jura MR. 2018. Production of liquid organic fertilizer from offal waste of skipjack (*Katsuwonus pelamis*). Jurnal Akademika Kimia 7: 70–74.

Turcihan G, Isinibilir M, Zeybek YG, Eryalçın KM. 2022. Effect of different feeds on reproduction performance, nutritional components and fatty acid composition of cladocer water flea (*Daphnia magna*). Aquaculture Research 53: 2420–2430.

Vasina L, Kraievska I, Khudyi O, Khuda L, Cheban L. 2020. Application of an association of yeast and lactic acid bacteria to bioencapsulate carotenoids in *Daphnia magna* (Straus, 1820). Fisheries and Aquatic Life 28: 225–233.

Wibisono MA, Hastuti S, Herawati VE. 2016. Production of *Daphnia* sp. which cultured with combined tofu waste and animal feces in fertilizer based on fermented bread waste. Journal of Aquaculture Management and Technology 6: 187–196.

Wibisono MB, Paendong SMP, Lengkong MR, Kaunang ST. 2024. Development strategy of Betta fish (*Betta* sp.) business in Manado City, North Sulawesi-Indonesia. Formosa Journal of Sustainable Research 3: 1477–1492.

Wiratama TA, Kusumaningdyah DA, Zubaidah A, Hermawan D, Handajani H. 2021. The supplementation of *Daphnia magna* enriched ascorbic acid to improve the growth and survival rate of *Pterophyllum scalare*. Jurnal Ilmiah Perikanan dan Kelautan 13: 48–57.

Yan W-Z, Wang J, Wang Y-M, Zeng Y-H, Chi C-F, Wang B. 2024. Optimization of the preparation process and ameliorative efficacy in osteoporotic rats of peptide–calcium chelates from skipjack tuna (*Katsuwonus pelamis*) Meat. Foods 13: 2778.

Zainudin S, Hartutik H, Sudjarwo E, Sjofjan O. 2024. Essential amino acid, short chain fatty acid and omega content of skipjack tuna offal meal and its effects on the nutrient digestibility of local chicken. Advances in Animal and Veterinary Sciences. 12: 942–949.

Copyright © 2025 by Authors, published by Indonesian Society for Scientific Aquaculture.
This is an open-access article distributed under the CC BY-SA 4.0 License
(https://creativecommons.org/licenses/by-sa/4.0/).