Peningkatan Efisiensi Pakan dan Performa Pertumbuhan Ikan Betok (*Anabas testudineus*) yang Dipelihara pada Periode Pemuasaan yang Berbeda

Improving Feed Efficiency and Growth Performance of Climbing Perch (*Anabas testudineus*) Reared at Different Periods of Starvation

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ABSTRAK

Pakan ikan diketahui menyumbang 60-70% dari total biaya akuakultur, sehingga menjadi tantangan yang signifikan bagi pembudidaya. Untuk mengatasi masalah ini, penelitian ini mengeksplorasi efektivitas pemuasaan periodik dalam meningkatkan efisiensi pakan dan kinerja pertumbuhan ikan sekaligus mengurangi biaya pembelian pakan. Metode yang digunakan adalah rancangan acak lengkap (RAL) yang dianalisis menggunakan ANOVA. Empat perlakuan diterapkan dengan masing-masing tiga ulangan. Perlakuan tersebut tterdiri dari P0 (tanpa puasa), P1 (satu hari puasa diikuti dengan satu hari pemberian pakan), P2 (satu hari puasa dan dua hari pemberian pakan), dan P3 (satu hari puasa dan tiga hari pemberian pakan). Parameter yang diamati meliputi efisiensi pakan, pertumbuhan panjang dan berat mutlak, serta tingkat kelangsungan hidup ikan. Hasil penelitian menunjukkan bahwa kelaparan periodik secara signifikan berdampak pada pertumbuhan berat badan absolut dan efisiensi pakan (P<0,05). Namun, tidak berpengaruh pada tingkat kelangsungan hidup dan pertumbuhan panjang mutlak. Di antara perlakuan yang diberikan, P1 menunjukkan hasil terbaik, dengan efisiensi pakan 21,87%, pertumbuhan panjang 0,23 cm, pertumbuhan berat 0,22 g, dan tingkat kelangsungan hidup 100%. Kesimpulannya, penelitian ini menemukan bahwa pemuasaan berkala yang dikombinasikan dengan pemberian pakan secara signifikan dapat meningkatkan efisiensi penggunaan pakan ikan dan menghemat biaya pembudidaya ikan.

Kata kunci: Pertumbuhan kompensasi, efisiensi pakan, pemberian pakan secara berkala

ABSTRACT

Fish feed is known to account for 60-70% of total aquaculture costs, posing a significant challenge to farmers. To address the issue, this study explored the effectiveness of periodic starvation in improving feed efficiency and growth performance of climbing perch while reducing the cost of purchasing feed. The method used was a completely randomized design (CRD) analyzed using ANOVA. Four treatments were applied with three replicates each. The treatments consisted of P0 (no fasting), P1 (one day of fasting followed by one day of feeding), P2 (one day of fasting and two days of feeding), and P3 (one day of fasting and three days of feeding). The parameters observed included feed efficiency, growth in length and absolute weight, and fish survival rates. The results showed that periodic starvation significantly impacted the absolute body weight growth and feed efficiency (P<0.05). However, no effect was observed on the survival rates and absolute length growth. Among the treatments, P1 showed the best results, with feed efficiency of 21.87%, length growth of 0.23 cm, weight growth of 0.22 g, and survival rate of 100%. In conclusion, this study found that periodic starvation combined with feeding could significantly improve fish feed use efficiency and save fish farmers' costs.

Keywords: Compensatory growth, feed efficiency, periodic feeding

INTRODUCTION

Climbing perch, scientifically known as *Anabas testudineus*, is a freshwater fish found in the wild. In Indonesia, it is also referred to as bethok or bethik in Java, Puyu in West Sumatra, and Papuyu in the Banjar language. This fish is rich in essential nutrients and has great potential in Asia (Al-Rasheed et al., 2018). Meanwhile, the English name climbing perch is due to its unique ability to climb onto the land (Aryzegovina et al., 2022).

Successful cultivation of climbing perch has been carried out in the control media, but the slow growth performance remains a challenge for aquaculture expansion. Approximately 6-7 months are needed for the fish to reach a size of 8-10 cm, which is considered too long (Alang *et al.,* 2020). Subsequently, feed contributes the highest input, reaching 60-70% of the total production cost in aquaculture (Yanti & Widaryati, 2021). In general, starvation has been suggested as a solution to reduce the cost of production offering several benefits, including growth increment and feed use (Widyantoro *et al.,* 2014), and reduction in cost production (Mulyani *et al.,* 2014). It also triggers compensatory growth, allowing fish to make up for energy after starvation (Hendrianto *et al.,* 2018; Zeng *et al.,* 2012). Periodic starvation methods enable better efficiency than daily feed for fish rearing (Mulyani *et al.,* 2014).

Compensatory growth is more significant than the average growth phase after nutrient deprivation (Ali *et al.,* 2003; Oliveira *et al.,* 2020). Fish tend to have an increased appetite after the re-feeding phase, known as hyperphagia. During this phase, a temporary increase occurs in appetite that eventually returns to normal (Nurhuda *et al.,* 2018). Therefore, periodic feeding can lead to better growth. A study on tilapia fed for one day and three days showed the best growth, feed efficiency, and survival results compared to other treatments (Mulyani *et al.,* 2014). It was found that starvation could activate compensatory growth and reduce production costs.

The treatments in catfish reared with a recirculation system significantly affected growth and feed use (Widyantoro *et al.,* 2014). According to Mustofa *et al.* (2018), the best feed efficiency and conversion ratio values for goldfish were achieved by treating with one day of starvation followed by one day of re-feeding. Based on a study by Hendrianto *et al.* (2018), white snapper fish fed for five days and then starved for one day (treatment A) had better feed conversion ratio, daily feed consumption, weight gain per day, and feed efficiency than those fed daily (treatment B). Armanda *et al.* (2019) also found that catfish showed the highest results in absolute weight and length growth and feed conversion ratio when subjected to a 12-hour starvation treatment. In contrast, Sari *et al.* (2017), stated that tilapia's growth and feed efficiency in ponds were significantly affected by one-day starvation followed by one-day re-feeding. It was also found that periodic starvation reduced feed use by an average of 45.01%.

According to a 2019 study by Markam et al. on climbing perch (*Anabas testudineus*), fish that were starved and then fed again showed changes in their body condition index and physiological reactions that suggested the possibility of compensatory growth. The use of intermittent feeding in this species is also supported by a study titled "The Effects of Starvation and Refeeding on Certain Biochemical and Hematological Parameters in *Anabas testudineus*," which found that refeeding induced a recovery response that could improve growth efficiency and that starvation resulted in significant physiological adaptations (Kumar et al., 2014).

Despite the numerous available studies, periodic starvation treatment has never been investigated in climbing perch. Therefore, this study aimed to analyze climbing perch's feed efficiency and growth performance and determine the best treatment during rearing using different starvation periods.

MATERIALS AND METHODS

Sample Preparation

Climbing perch, initially 5 ± 0.5 cm in length, was obtained from a farmer in Pemulutan, South Sumatra, and commercial feed PF 500 with a protein content of 39% was used. The fish was acclimatized for seven days in a 1x1 m^2 concrete pond and fed ad libitum. Fish length and weight were measured at the start of the study as baseline data.

Experimental Design

This experiment was carried out in four different treatments, each with three replications. The treatments were control or P0 (fed daily), P1 (starved for one day and then fed for one day), P2 (starved for one day and then fed for two days), and P3 (starved for one day and then fed for three days). The purpose of this design was to assess the compensatory growth response and feed utilization under varying feeding frequencies using comparable techniques used in Mustofa et al. (2018) and Mulyani et al. (2014) research.

A completely randomized design (CRD) was used to analyze the data. For the experiment, 12 fish tanks of 25x25x25 cm^3 were used. These tanks were cleaned and disinfected using 2 mg L^{-1} potassium permanganate for 24 hours and dried before use. Each tank was filled with 16 cm of water, equivalent to 10 liters, and a density of 2 fish L^{-1} (Azrianto *et al.,* 2018). Using 20 fish in 10 liters of water per aquarium, as recommended by Azrianto et al. (2018), the number of fish per treatment unit was calculated using a stocking density of 2 fish per liter.

Aerators were installed in each aquarium to supply oxygen and the fish were fed three times daily using the satiation method. The water in the tanks was changed every three days, with about 10% of the total volume disposed to maintain the water quality during the study. Fish sampling was performed every 12 days throughout the study, including dead fish which were separated, weighed, and measured to monitor growth and body condition changes during the experiment.

Analysis Methods

The survival rate, absolute weight growth, absolute length growth, and feed efficiency were analyzed at the end of the treatment (Effendi, 2002; Afrianto & Evi, 2005).

$$SR\ (\%)=\frac{N_t}{N_0}\times 100\% \quad (1)$$

Where: SR = Survival Rate (%); Nt = Total fish at the end of the raising period (g); and N0 = Total fish at the beginning of the raising period (g).

$$AGR=W_t-W_0 \quad (2)$$

Where: AGR = Absolute Weight Growth (g); Wt = The average weight of fish at the end of the study (g); and Wo = The average weight of fish at the start of the study (g).

$$ALG=L_t-L_0 \quad (3)$$

Where: ALG = Absolute Length Growth (cm); Lt = the average length at the end of the study (cm); and Lo = the average length at the start of the study (cm).

$$FE=\left(\left(\frac{(W_t+D)-W_0}{F}\right)\times 100\%\right) \quad (4)$$

Where: FE = Feed efficiency; Wt = The fish biomass at the end of rearing (g), D = The dead fish biomass during the study (g); W0 = The fish biomass at the beginning of rearing (g); and F = The amount of feed given during rearing (g)

Water quality parameters, such as pH, temperature, and dissolved oxygen, were measured with a portable pH meter, thermometer, and dissolved oxygen (DO) meter respectively using a Hanna water quality instrument (HI9829). Ammonia was measured once every 12 days during the study using the phenate method (APHA, 2012).

Statistical Analysis

The mean and standard deviation were analyzed using descriptive statistics. The data were calculated in a one-way variance analysis (ANOVA) by SPSS to verify significant treatment differences. When $p < 0.05$, the least significant difference (LSD) test was used.

RESULTS AND DISCUSSION

Feed efficiency measures the effectiveness of protein in increasing the weight of fish (Dvergedal *et al.,* 2019). It is calculated by comparing the weight of fish gained to feed consumed (Yanti & Widaryati, 2021). Table 1 shows data on the growth and feed efficiency of climbing perch.

Table 1. The different starvation periods affected feed efficiency (FE) and absolute growth of climbing perch

Treatment	FE (%) BNT α 0.05 = 3.02	Growth	
		Length (cm)	Weight (g) LSD α 0.05 = 0.05
P0	12.91 ±1.36[a]	0.21 ±0.03[NS]	0.22 ± 0.03[ab]
P1	21.87 ±1.91[b]	0.23 ±0.02[NS]	0.22 ± 0.02[ab]
P2	23.65 ±0.85[b]	0.26 ±0.02[NS]	0.27 ± 0.02[b]
P3	13.50 ±2.19[a]	0.21 ±0.01[NS]	0.19 ± 0.03[a]

[1] Values shown are mean ± SD (n = 3). Different superscripts (a, b, c) in the same column show that the means, significantly differ and not significant (NS) ($p < 0.05$) among combination treatments by ANOVA.

The data presented in Table 1 showed that different starvation periods affected feed efficiency and absolute growth rate. Based on the least significant difference test, there was no significant difference between P1 and P2 treatments. On the other hand, there was a significant difference between these treatments with P0 and P3. The analysis of variance also suggested that starvation treatment significantly impacted the absolute weight growth but did not significantly impact the absolute length growth.

The compensatory growth processes, especially hyperphagia—a physiological reaction in which fish experience a brief increase in hunger following a period of feed deprivation—are responsible for the observed improvement in feed efficiency and growth performance under P1 and P2 treatments. Rapid biomass recovery and effective feed conversion are made possible by this reaction (Ali et al., 2003; Nurhuda et al., 2018). Hormonal changes that boost hunger and metabolic activity after refeeding, such as elevated ghrelin and thyroid hormones, cause hyperphagia (Deal & Volkoff, 2020).

Despite the statistical similarity between P1 and P2, P2's numerical values were somewhat greater. P1 showed a balanced growth profile and a more stable survival rate, though. Over time, a more diluted hyperphagic impact would have resulted from P2's prolonged refeeding interval, which may have reduced the acute physiological reaction seen in P1. This implies that in order to maximize compensatory growth responses without sacrificing stability or survival, shorter and more frequent refeeding cycles (as in P1) would be more successful.

Feed efficiency value is used to determine the effectiveness of consumption (Charles Bai *et al.,* 2022). A more significant increase in fish body weight means a greater feed efficiency (Yanti & Widaryati, 2021). Although the feed efficiency of P1 and P2 was low (<50%) (Craig & Helfrich, 2017), the value was still categorized as a high growth rate. The best result was produced by the P2 group (1-day starvation and 2-day re-feed), which yielded the most significant feed efficiency and the highest growth rate. Different results were reported in Tilapia by Mulyani *et al.* (2014) where one day of starvation and re-feed produced the most excellent feed efficiency. The results suggest that although periods of starvation might show different responses to several kinds of fish, this method can be used to increase growth rates equivalent to or even higher than those of fish without starvation. Many fish species tolerate starvation throughout their life history (Wang *et al.,* 2019). It is assumed periodic starvation allows fish to catch up with growth after exposure. Fish subjected to starvation can reach the same body weight or even higher levels than those without starvation, a phenomenon called compensatory growth (Nurhuda *et al.,* 2018).

Compensatory growth, also known as catch-up growth, is a phenomenon that leads to the same body size as the treatment without starvation (Skalski *et al.,* 2005). This growth is mainly caused by food consumption, which is more significant than the treatment without starvation (Ali *et al.,* 2003). Fish appetite increases after the re-feeding phase due to hyperphagia, which occurs after starvation for a certain period. This appetite eventually returns to normal, usually within 2-3 days (Nurhuda *et al.,* 2018). However, this study showed that slightly different hyperphagia occurred within one day after re-feeding, as also reported by Mustofa *et al.* (2018).

Fish that experience starvation period do not receive food every day, which consequently increases hunger. In several starvation cycles, the fish adjust physiological conditions to conserve energy by reducing activity and metabolism. Periodical starvation also causes an increase in the concentration of thyroxine and triiodothyronine in fish plasma when fed again (Arslan *et al.,* 2014). Starvation also increases plasma osmolality values, showing a physiological response of the fish in regulating the body's osmotic concentration. When fish starve, their nutritional status decreases, which affects their body's osmotic concentration, which is reflected in the plasma osmolality value. This leads to maximal use of feed nutrients for growth. The thyroid hormone may play a role in stimulating growth during starvation (Deal & Volkoff, 2020).

Factors that affect fish growth can be categorized into two types, namely internal and external. Internal factors include fish age and genetic characteristics such as heredity, disease resistance, and food useability. On the other hand, external factors relate to the environment, including physical and chemical properties of the water, space for movement, and food availability (Silaban *et al.,* 2012). A study by Mustofa *et al.* (2018) showed that the starvation period followed by adequate feeding could increase feed use effectiveness but did not accelerate fish growth. Similar results were obtained in this study where climbing perch subjected to starvation had improved growth, which was not significantly different from the control, but enhanced feed use effectiveness.

Table 2. Survival Rate (SR) of fish during the study

Treatment	Replications			Total	Mean SR (%)
	1	2	3		
P0	100	95	100	295	98.33 ±2.89
P1	100	100	100	300	100.00 ±0.00
P2	100	100	100	300	100.00±0.00
P3	100	100	100	300	100.00 ±0.00

According to Table 2, the climbing perch survival rate with starvation treatment showed a higher percentage than without starvation. The survival rate did not significantly affect treatments, reaching >95% and classified as very high. During the study, the fish adapted to the environment and feeding cycle. Water quality remained in a range that supported the living requirements of climbing perch (Table 3). Feed was efficiently consumed, and there was no competition between the fish. Furthermore, there were no pests affecting the disease during the study. This finding aligns with *Zulkhasyni et al.* (2017), who emphasized the impact of water quality, feed availability, and competition among organisms and pests on fish survival.

Table 3. Water quality of the media during the study

Treatment	Temperature (°C)	pH	Dissolved oxygen (mg L^{-1})
P0	24.8–27.6	6–7.2	3.61-4.83
P1	24.9–27.6	6–7.4	3.75–4.64
P2	24.8–27.6	6.2–7.4	3.27–4.82
P3	24.9–27.5	6–7.4	3.43–4.93

Table 4. Ammonia values during the study

Day	Ammonia (mg L^{-1})			
	P0	P1	P2	P3
1	0.04±0.01	0.04±0.01	0.04±0.01	0.05±0.01
12	0.03±0.01	0.02±0.01	0.03±0.01	0.03±0.01
24	0.03±0.01	0.03±0.01	0.04±0.01	0.04±0.01
36	0.05±0.01	0.04±0.01	0.05±0.01	0.05±0.01

Water quality measurements show adequate conditions to support climbing perch survival, as presented in Table 3. The temperature for supporting climbing perch growth ranges from 22-28 °C, and a pH of 6-8 is considered appropriate (Atika et al., 2012). In addition, the dissolved oxygen (DO) level should not be less than 5 mg L-1 (Effendi, 2003; Rouf *et al.,* 2023). The concentration of dissolved oxygen (DO) in water influences fish metabolism and biological functions. Inadequate DO levels can severely hinder fish growth and feed intake (Abdel-Tawwab *et al.,* 2015; Ali *et al.,* 2022).

The ANOVA test result showed that all treatments did not significantly affect the ammonia value as presented in Table 4, primarily because water quality was well-managed and monitored every three days during each treatment. The ammonia concentration remained within the acceptable range for freshwater fish, namely less than 0.1 mg L-1 (Effendi, 2003).

CONCLUSION

Periodic hunger has a major impact on climbing perch growth by increasing weight gain and feed utilization efficiency without having a negative impact on length growth or survival. With a 100% survival rate and good feed efficiency, P1 (one day of hunger followed by one day of feeding) produced the most balanced and advantageous results among the treatments.

In climbing perch aquaculture, this study suggests using periodic fasting, namely the P1 treatment, as an effective feeding technique to save feed costs without sacrificing growth performance. However, additional influencing elements like fish density, feed composition, and water quality should be taken into account for future implementation in commercial settings since they may have an impact on the strategy's overall results.

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