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Effect of Feeding Frequency of Ulva lactuca-Supplemented Diet on Growth Performance and Feed Efficiency of Nile Tilapia *(Oreochromis niloticus)*

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Abstract :

This study aimed to evaluate the effect of feeding frequency of a diet supplemented with 12% Ulva lactuca meal on the growth performance, feed efficiency, and survival rate of Nile tilapia (Oreochromis niloticus). The experiment was conducted for 60 days at the Noekele Fish Hatchery Center, Kupang Regency, Indonesia. A Completely Randomized Design (CRD) was employed with three feeding frequency treatments and three replicates: P1 (feeding twice daily), P2 (feeding three times daily), and P3 (feeding four times daily). Parameters observed included weight gain, specific growth rate (SGR), feed efficiency, survival rate, and water quality. Data were analyzed using one-way analysis of variance (ANOVA) followed by the Least Significant Difference (LSD) test at a 95% confidence level. The results showed that feeding frequency significantly affected growth performance, feed efficiency, and survival rate of Nile tilapia ($P<0.05$). The highest performance was obtained in treatment P3, with a weight gain of 7.72 ± 0.77 g, specific growth rate of 2.41 ± 0.15% day^{-1}, feed efficiency of 76.66 ± 5.58%, and survival rate of 100%. These values were significantly higher than those observed in P1 and P2. Increased feeding frequency likely improved nutrient availability and utilization, resulting in enhanced growth and feed conversion efficiency. Water quality parameters remained within the optimal range for Nile tilapia culture, with temperatures of 26–30°C and pH values of 7.0–8.5 throughout the study. In conclusion, feeding Nile tilapia with a diet containing 12% Ulva lactuca meal four times per day is the optimal feeding frequency to improve growth performance, feed efficiency, and survival rate

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INTRODUCTION

Nile tilapia (*Oreochromis niloticus*) is one of the most important freshwater aquaculture species worldwide due to its rapid growth rate, high adaptability to various environmental conditions, disease resistance, and strong market demand. The species contributes significantly to global aquaculture production and plays an important role in food security and rural livelihoods. However, feed remains the largest operational cost in tilapia farming, accounting for approximately 60–70% of total production expenses. Improving feed utilization through effective feeding management and alternative feed ingredients is therefore essential to enhance productivity and sustainability in aquaculture systems (Abdel-Tawwab et al., 2022; Abd El-Hack *et al*., 2022).

One strategy to improve feed efficiency is the utilization of alternative feed ingredients derived from locally available resources. Marine macroalgae have attracted considerable attention as

potential feed ingredients because they contain valuable nutrients and bioactive compounds that support fish growth and health. Among various seaweed species, the green macroalga *Ulva lactuca* possesses considerable nutritional value, including proteins, carbohydrates, essential minerals, vitamins, and antioxidant compounds. Previous studies have demonstrated that the inclusion of U. lactuca in aquafeeds can improve nutrient digestibility, digestive enzyme activity, growth performance, and physiological responses of cultured fish. Furthermore, macroalgae-based feed ingredients may reduce dependence on conventional feed resources and contribute to environmentally sustainable aquaculture production (Glencross *et al.*, 2020; Suryaningrum & Samsudin, 2020; Mohamed *et al*., 2020).

In addition to feed composition, feeding management is a critical factor influencing fish growth and production efficiency. Feeding frequency directly affects feed intake, nutrient absorption, metabolism, and feed conversion efficiency. Appropriate feeding frequency ensures a continuous supply of nutrients to fish, thereby maximizing nutrient utilization and minimizing feed losses. Conversely, insufficient feeding frequency may limit nutrient availability and reduce growth, whereas excessive feeding may increase feed wastage, deteriorate water quality, and decrease production efficiency. Therefore, determining the optimal feeding frequency is essential for improving growth performance and feed utilization in aquaculture operations (Cadorin *et al*., 2022; Dauda *et al*., 2021).

Several studies have reported that feeding frequency significantly affects the growth performance of Nile tilapia. Fava *et al*. (2022) found that increasing feeding frequency improved weight gain and feed utilization efficiency in Nile tilapia fingerlings. Similarly, Hisano *et al*. (2021) reported that feeding frequency significantly influenced growth performance and water quality in Nile tilapia cultured under biofloc systems. Furthermore, Hamed *et al*. (2024) demonstrated that feeding frequency interacts with environmental conditions and can affect growth, immune response, and overall fish performance. These findings indicate that feeding frequency plays a vital role in maximizing fish growth and feed efficiency. The application of Ulva lactuca as a dietary supplement has also shown promising results in Nile tilapia culture. Carvalho Chagas *et al*. (2025) reported that dietary inclusion of *U. lactuca* improved growth performance and nutrient utilization in juvenile Nile tilapia. Likewise, Dernekbaşı et al. (2025) demonstrated that *U. lactuca* supplementation enhanced digestive enzyme activity, antioxidant status, and growth performance of Nile tilapia reared under different feeding regimes. These findings suggest that the nutritional and bioactive properties of *U. lactuca* may contribute positively to fish growth and physiological performance.

Although the effects of feeding frequency and *Ulva lactuca* supplementation have been investigated separately, studies evaluating the combined effect of feeding frequency and diets containing *U. lactuca* on Nile tilapia performance remain limited. Consequently, information regarding the optimal feeding frequency for fish fed diets supplemented with U. lactuca is still insufficient. Considering that the nutritional composition and digestibility of U. lactuca may influence nutrient utilization and growth responses, further investigation is required to identify the most effective feeding strategy for maximizing fish performance.

Therefore, this study aimed to evaluate the effect of different feeding frequencies of a diet containing 12% *Ulva lactuca* meal on the growth performance, feed efficiency, and survival rate of Nile tilapia (*Oreochromis niloticus*). The results of this study are expected to provide scientific information regarding efficient feeding management practices and support the utilization of locally available macroalgae resources for sustainable Nile tilapia aquaculture.

MATERIALS AND METHODS

Study Site and Experimental Period

The study was conducted from August to September 2025 for 60 days at the Noekele Fish Hatchery Center (BBIS Noekele), Kupang Regency, East Nusa Tenggara, Indonesia.

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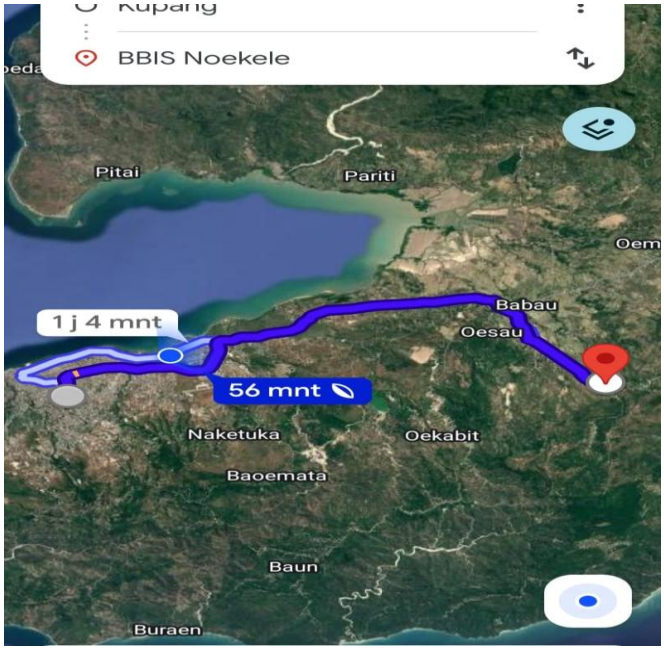

Figure 1. *Peta BBIS Noekele*

Experimental Fish and Feed Preparation

Nile tilapia (*Oreochromis niloticus*) juveniles were used as experimental fish. The fish were acclimatized prior to the experiment and reared under controlled culture conditions. The experimental diet consisted of 88% commercial feed and 12% *Ulva lactuca* meal. The seaweed meal was mixed thoroughly with the commercial feed using tapioca flour as a binder. The feed mixture was then formed into pellets and dried before use.

Experimental Design

The experiment employed a Completely Randomized Design (CRD) consisting of three feeding frequency treatments with three replicates each:

P1 = Feeding twice daily
P2 = Feeding three times daily
P3 = Feeding four times daily

Fish were fed according to the assigned treatment throughout the 60-day experimental period. The amount of feed administered was adjusted according to fish biomass and culture conditions.

Growth Performance Parameters

Weight Gain (WG)

Weight gain was calculated using the following equation:

$$\mathbf{WG = Wt - W0}$$

where:
WG = Weight gain (g)
(Wt) = Final average body weight (g)
(W0) = Initial average body weight (g)

Specific Growth Rate (SGR)

The specific growth rate was calculated according to the following formula:

$$SGR = \frac{\ln W_t - \ln W_0}{t} \times 100$$

where:
SGR = Specific growth rate (% day^{-1})
(Wt) = Final average body weight (g)
(W0) = Initial average body weight (g)
(t) = Culture period (days)

Feed Efficiency (FE)

Feed efficiency was calculated using the following equation:

$$FE = \frac{(W_t + W_d) - W_0}{F} \times 100$$

where:
FE = Feed efficiency (%)
(Wt) = Final biomass (g)
(Wd) = Biomass of dead fish during the experiment (g)
(W0) = Initial biomass (g)
(F) = Total feed consumed during the experiment (g)

Survival Rate (SR)

Survival rate was calculated using the following formula:

$$SR = \frac{N_t}{N_0} \times 100$$

where:
SR = Survival rate (%)

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(Nt) = Number of fish at the end of the experiment
(N0) = Number of fish at the beginning of the experiment

Water Quality Monitoring

Water quality parameters monitored during the experiment included temperature and pH. Measurements were conducted every seven days during the water exchange period. Water temperature was measured using a thermometer, while pH was determined using a digital pH meter.

Statistical Analysis

All data were expressed as mean ± standard deviation. The effects of feeding frequency on growth performance, feed efficiency, and survival rate were analyzed using one-way analysis of variance (ANOVA) at a 95% confidence level. When significant differences among treatments were detected ($P < 0.05$), Duncan's Multiple Range Test (DMRT) was performed to identify differences between treatment means. Statistical analyses were conducted using SPSS software version 25.0.

RESULTS AND DISCUSSION

Weight Gain

The effect of feeding frequency of a diet supplemented with Ulva lactuca meal on the weight gain of Nile tilapia is presented in Figure 1.

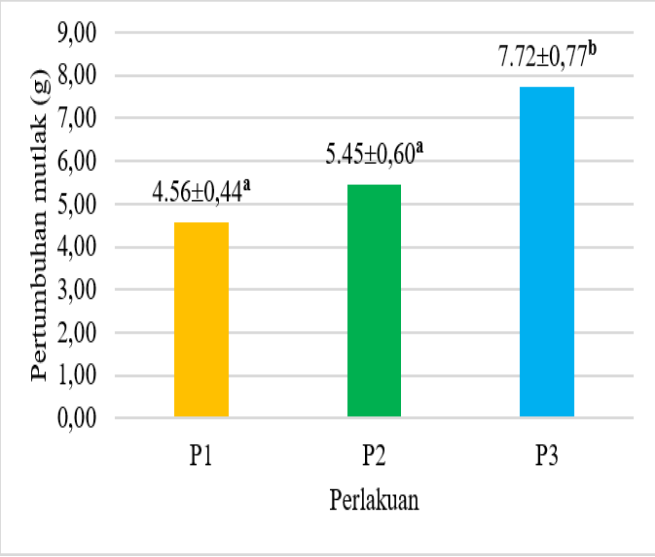

Figure 1. Tilapia fish after treatment

The results showed that feeding frequency significantly affected the weight gain of Nile tilapia ($P<0.05$). The highest weight gain was observed in treatment P3 (feeding four times daily), reaching 7.72 ± 0.77 g, followed by P2 with 5.45 ± 0.60 g and P1 with 4.56 ± 0.44 g. Statistical analysis indicated that P3 differed significantly from P1 and P2, while no significant difference was observed between P1 and P2.

The higher weight gain observed in P3 indicates that more frequent feeding improved nutrient availability and utilization. Frequent feeding provides a continuous supply of nutrients required for maintenance and tissue growth, thereby enhancing protein deposition and biomass accumulation. Furthermore, feeding fish in smaller portions at shorter intervals may improve feed digestibility and reduce nutrient losses. Similar findings were reported by Fava *et al*. (2022), who demonstrated that increased feeding frequency significantly improved weight gain in Nile tilapia fingerlings. Likewise, Dauda *et al.* (2021) reported that appropriate feeding frequency enhanced nutrient utilization efficiency and growth performance in Nile tilapia culture systems.

The inclusion of 12% *Ulva lactuca* meal in the diet may have further contributed to growth enhancement due to its nutritional content, including protein, minerals, vitamins, and bioactive compounds that support metabolic activities and tissue development. Similar improvements in growth performance associated with *U. lactuca* supplementation have been reported by Carvalho Chagas *et al.* (2025) and Dernekbaşı *et al.* (2025). Moreover, Glencross *et al*. (2020) highlighted the potential of algae-based feed ingredients as sustainable alternatives capable of supporting fish growth and reducing dependence on conventional feed resources.

Specific Growth Rate

The specific growth rate (SGR) of Nile tilapia under different feeding frequencies is shown in Figure 2.

The SGR values obtained in this study were 1.78 ± 0.11% day^{-1}, 1.97 ± 0.14% day^{-1}, and 2.41 ± 0.15% day^{-1} for treatments P1, P2, and P3, respectively. Statistical analysis revealed that

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feeding frequency significantly influenced SGR ($P<0.05$), with the highest value recorded in P3.

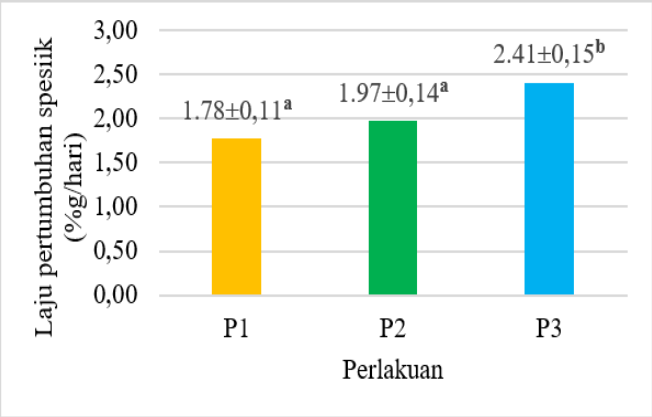

Figure 2. Specific growth of tilapia after treatment

The superior SGR observed in fish fed four times daily suggests that more frequent feeding improved nutrient absorption and metabolic efficiency. Fish require a consistent nutrient supply to sustain physiological functions and growth processes. Feeding at longer intervals may result in periods of nutrient deficiency, whereas more frequent feeding ensures continuous nutrient availability. According to Cadorin *et al*. (2022), feeding frequency directly affects digestion efficiency, nutrient assimilation, and growth performance in Nile tilapia. Similar findings were reported by Hisano *et al*. (2021), who observed significant improvements in growth performance of Nile tilapia under optimized feeding frequencies.

The nutritional contribution of *U. lactuca* may also support growth by providing additional protein and bioactive compounds that enhance nutrient utilization. Mohamed et al. (2020) demonstrated that dietary inclusion of *U. lactuca* improved nutrient utilization and growth performance in Nile tilapia. Likewise, Suryaningrum and Samsudin (2020) reported that Ulva-based feed ingredients improved nutrient digestibility and growth efficiency in cultured fish.

Feed Efficiency

Feed efficiency values of Nile tilapia fed at different feeding frequencies are presented in Figure 3.

The highest feed efficiency was recorded in P3 (76.66 ± 5.58%), followed by P2 (70.16 ± 6.17%) and P1 (68.69 ± 9.70%). Statistical analysis showed significant differences among treatments ($P<0.05$), indicating that feeding frequency affected the ability of fish to convert feed into body mass.

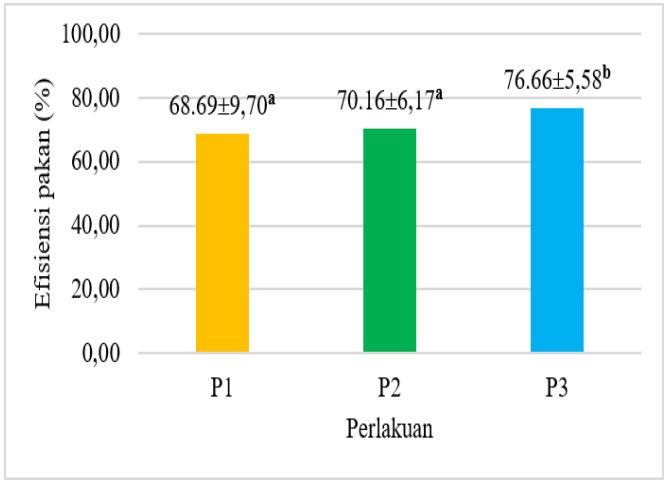

Figure 3. Efficiency of tilapia feed after treatment

Higher feed efficiency in P3 suggests that frequent feeding improved feed utilization by maintaining nutrient availability within the digestive tract. Appropriate feeding intervals allow fish to digest and absorb nutrients more effectively while minimizing feed losses. As a result, a greater proportion of consumed feed is converted into growth rather than being wasted. Similar observations were reported by Fava *et al.* (2022), who demonstrated that increased feeding frequency improved feed utilization efficiency in Nile tilapia fingerlings. Furthermore, Cadorin et al. (2022) found that feeding management significantly influences nutrient retention and feed conversion efficiency in tilapia culture.

The relatively high feed efficiency observed in this study may also be associated with the inclusion of *U. lactuca* meal, which provides additional nutrients and bioactive compounds that potentially improve digestive performance and nutrient assimilation. Dernekbaşı *et al*. (2025) reported enhanced digestive enzyme activity in Nile tilapia fed diets supplemented with *U. lactuca*, while Zablon *et al*. (2022) emphasized that improved nutrient utilization is closely related to better feed conversion and growth performance.

Survival Rate

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The survival rate of Nile tilapia under different feeding frequencies is presented in Figure 4.

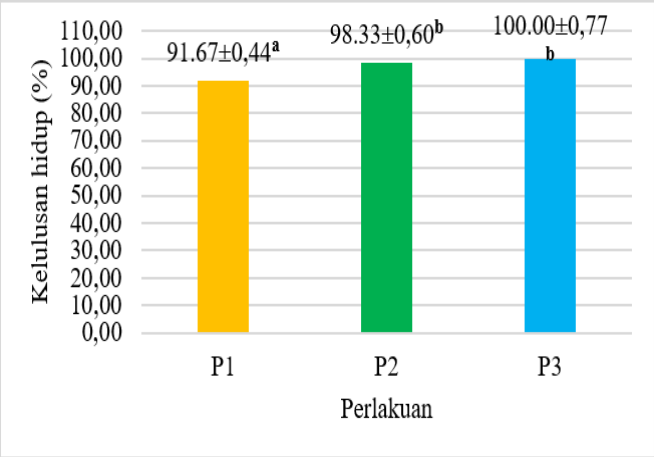

Figure 4. Survival rate of tilapia after treatment

The survival rates recorded in treatments P1, P2, and P3 were 91.67%, 98.33%, and 100%, respectively. Statistical analysis indicated that feeding frequency significantly affected fish survival ($P<0.05$). The highest survival rate was observed in fish fed four times daily.

The improved survival rate in P3 may be attributed to better nutritional status and reduced competition for feed among fish. Frequent feeding ensures a more uniform feed distribution and reduces aggressive behavior associated with feed competition. Adequate nutrient intake also supports physiological functions and stress resistance, thereby improving fish survival. Hamed *et al.* (2024) reported that feeding frequency significantly influences fish health, immune response, and overall performance. In addition, Hisano et al. (2021) found that proper feeding management contributes to maintaining high survival rates and favorable culture conditions in Nile tilapia production systems.

Water Quality

Water quality parameters measured during the study are presented in Table 1.

The water temperature ranged from 26 to 30°C, while pH values ranged from 7.0 to 8.5. These values were within the acceptable range for Nile tilapia culture and complied with national aquaculture standards. Suitable water quality conditions are essential for maintaining fish health, growth, and survival.

Parameter	**Bulan**		**SNI**
Suhu (^{0}C)	**Agustus**	**September**	
25^{0}C - 32^{0}C	26-30	26-30	6,5 - 8,5
pH	7.0 - 8.55	7.0 - 8.55	

Temperature influences metabolic rate, feed consumption, and physiological activities of fish. The temperature range observed in this study was considered optimal for Nile tilapia growth. Similarly, pH values remained within the recommended range for freshwater aquaculture, supporting efficient physiological and biochemical processes. According to Abd El-Hack et al. (2022), environmental factors such as temperature and water quality play a crucial role in determining fish growth and physiological performance. Likewise, Abdel-Tawwab *et al.* (2022) emphasized that maintaining suitable environmental conditions is critical for maximizing growth performance and feed utilization in Nile tilapia culture. Therefore, the favorable water quality conditions observed throughout the experiment likely contributed to the high growth performance and survival rates recorded in this study.

CONCLUSIONS

Feeding frequency of a diet containing 12% Ulva lactuca meal significantly affected the growth performance, feed efficiency, and survival rate of Nile tilapia (Oreochromis niloticus) ($P<0.05$). The highest performance was achieved in fish fed four times daily (P3), resulting in a weight gain of 7.72 ± 0.77 g, specific growth rate of 2.41 ± 0.15% day^{-1}, feed efficiency of 76.66 ± 5.58%, and survival rate of 100%. These findings indicate that increasing feeding frequency improved nutrient utilization and growth performance of Nile tilapia fed a diet supplemented with U. lactuca. Therefore, feeding four times daily is recommended as the optimal feeding strategy for enhancing growth, feed utilization efficiency, and survival of Nile tilapia under the conditions of this study.

Recommendation: Further studies are needed to evaluate different inclusion levels of Ulva lactuca

meal and feeding frequencies under various culture systems to optimize its application in sustainable aquaculture.

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AUTHOR CONTRIBUTIONS

Conceptualization, C.G.U. and R.T.; methodology, C.G.U.; investigation, C.G.U.; data curation, C.G.U.; formal analysis, C.G.U. and R.T.; writing—original draft preparation, C.G.U.; writing—review and editing, R.T. and I.F.; supervision, R.T. and I.F. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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