



RESEARCH ARTICLE

Integrating Agroforestry and Aquaculture: Effects of *Moringa oleifera* Leaf Extract on Growth Performance of White Snapper (*Lates calcarifer*)

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ABSTRACT

The integration of agroforestry and aquaculture systems has been increasingly explored to improve resource utilization and support sustainable food production. This study evaluates the potential of moringa (*Moringa oleifera*), a multifunctional agroforestry species, as a feed supplement for white snapper (*Lates calcarifer*). An experimental study was conducted using a completely randomized design with four dietary treatments: 0% (control), 2.5%, 5%, and 7.5% moringa leaf extract supplementation, each with three replicates, over a 28-day rearing period. Growth performance, including absolute length and weight gain, specific growth rate (SGR), survival rate (SR), and feed conversion ratio (FCR), was measured. The results showed that fish receiving moringa-supplemented feed generally exhibited higher growth values compared to the control. The highest average weight gain was observed in the 5% treatment (9.28 g), while the highest SGR was recorded in the 2.5% treatment (4.79% day⁻¹). Survival rates in all supplemented treatments reached 100%, compared to 90% in the control group, indicating favorable culture conditions and no adverse effects of supplementation. FCR values across treatments remained above 2, suggesting relatively low feed utilization efficiency. This may be related to the carnivorous feeding characteristics of white snapper, which can limit the effective use of plant-based feed components. Water quality parameters, including temperature, pH, and dissolved oxygen, remained within acceptable ranges throughout the study. This study provides empirical evidence supporting the integration of agroforestry biomass into aquaculture feed systems. The use of moringa as a locally available, renewable resource contributes to circular nutrient flows, reduces reliance on imported feed ingredients, and promotes environmentally sustainable aquaculture practices. These findings advance the development of integrated agroforestry–aquaculture systems as resilient and eco-efficient production models in tropical regions.

1. Introduction

Moringa (*Moringa oleifera*) has significant potential for agroforestry development and is a non-timber forest product that can help maintain natural balance and support sustainable forest management. This is due to its diverse benefits, including improved soil fertility and groundwater availability, increased land productivity, a natural food source for livestock and fish, and the restoration of degraded ecosystems. Furthermore, moringa is widely used as an intercrop in agroforestry efforts to supplement the yield of staple crops (Kumari et al., 2025). Known for its ease of cultivation and low maintenance, moringa can also be used as a supplementary feed in fish farming and as an alternative nutrient source to enhance fish growth. Moringa leaves are highly nutritious. Per 100 g of moringa powder contains 27.1 g of protein, 38.2 g of carbohydrates, 2.3 g of fat, 19.2 g of fiber, 7.5% water, and 205.0 g of calories (Pirmansyah et al., 2024). Moringa powder also contains numerous vitamins and minerals, as well as 10 amino acids and omegas 3, 6, and 9 (Pirmansyah et al., 2024).

White snapper (*Lates calcarifer*) is one of the most profitable saltwater fish species in the fisheries sector. Despite being carnivorous and having limited ability to digest complex cellulose, they are chosen for testing to determine the upper limit of plant protein inclusion without compromising growth, health, or feed conversion ratio (FCR). The ever-increasing demand for this species is driving increased white snapper production in aquaculture. However, white snapper cultivation still faces numerous challenges, including heterogeneous growth rates and dependence on imported feed (Santika et al., 2021).

One form of growth restriction for white snapper is size grading or heterogeneous growth, caused by several factors, including feed availability. Feed plays a crucial role in fish growth, especially if it contains protein, fat, carbohydrates, and minerals. Nutrients from the feed are initially used for body maintenance and cell repair, while the remainder supports growth (Handayani and Widodo, 2010). Feeding with appropriate nutritional content can increase the potential for fish survival. Furthermore, adequate feed availability also affects fish growth, where inadequate feed availability can lead to intense competition (Hiam et al., 2019; Rahmat, 2010). This intense competition will trigger the natural behavior of white snapper, namely cannibalism, due to high mortality. Cannibalism generally also occurs between larger fish and smaller fish (Puspanti, 2006).

According to Salim et al. (2023), food availability in the waters where white snapper live is closely related to the population size of the resource. This also aligns with the statement of Umar and Kartamihardja (2011) that the availability of natural food largely determines the growth and development of aquatic biota. Food is a factor that influences growth and determines the success of an individual's life. Prianto et al (2012) also explained that habitat factors, preferences for certain types of food, season, food size, food color and the age of the fish, influence aspects of fish eating habits. In addition to moringa, previous research shows that several plants have the potential as natural food for fish, especially white snapper, namely *sembukan* (*Paederia foetida*) (Salsabila et al., 2022), *Wolffia* (*Wolffia* sp.) (Alrozi et al., 2023), and *Nannochloropsis* sp. (Christian et al., 2023).

This research is also relevant to environmental sustainability, as moringa leaves are a sustainable, renewable natural resource. By utilizing this environmentally friendly natural resource as an alternative feed ingredient, this research also has the potential to support sustainable and environmentally friendly fish farming practices. Therefore, this research is expected to make a significant contribution to the development of more effective, efficient, and economically and environmentally sustainable methods for cultivating white snapper.

2. Materials and Methods

2.1. Time and location of research

This research was conducted from February–April 2025 at the Biological Botany Laboratory, FMIPA, University of Lampung, for the production of moringa leaf extract, and continued at the Lampung Marine Aquaculture Center (BBPBL), white snapper division, for fish culture.

2.2. Research Methods

This research was conducted experimentally using a completely randomized design (CRD) with four treatments of moringa leaf extract. Each treatment was replicated three repetitions. Each treatment used 10 white snapper fingerlings measuring 5 cm (Oktaria et al., 2022).

2.3. Moringa Leaf Extract Preparation

The washed moringa leaves are dried in the sun for 1–2 days until completely dry. Once dry, the moringa leaf *simplicia* is ground in a blender, sieved through a 60-mesh sieve to obtain a fine powder, and stored in a closed container. Then the extract is prepared by weighing 200 g of smooth moringa leaf *simplicia*, macerating it with 1000 mL of ethanol at a 1:5 ratio, and letting it stand for 3 × 24 hours. The mixture is then filtered using filter paper to separate the residue from the macerate. After that, the extract is evaporated using a rotary evaporator for 30 minutes, then transferred to a container/bottle and stored in the refrigerator until use (Oktaria et al., 2022).

2.4. Feed Preparation

The feed used was commercial K6 pellets with 50% protein and a size of 1.01–1.31 mm, suitable for the mouth opening of white snapper fry. Moringa leaf extract was mixed with an adhesive solution (propylene glycol and distilled water), sprayed on the pellets according to treatment (2.5%, 5%, and 7.5%), then dried in the sun until dry and stored. Feed was provided using an ad satiation method three times daily (8:00 a.m., 12:00 p.m., and 4:00 p.m.) (Khairumisah, 2023).

2.5. Fish Culture

Containers used in this study were 25 L jars; aeration was installed in each jar, which was then filled with seawater to 80% of its volume. During the stocking process, each rearing tank was filled with 10 fish. The fish were then measured for their initial length and weight, and water quality was recorded. The stocking of the fry was conducted at 4:30 p.m. because the temperature tends to be stable, thereby preventing stress on the fish (Surnawati et al., 2020). The composition of the commercial fish feed mixture with moringa leaf extract is explained in **Table 1**.

Table 1. The composition of the commercial fish feed mixture with moringa leaf extract

No	Treatment	Composition
1	Control	Feed pellet 1000 g
2	P1	2.5% moringa leaf extract (25 g) per feed pellet 1000 g
3	P2	5% moringa leaf extract (5 g) per feed pellet 1000 g
4	P3	7.5% moringa leaf extract (75 g) per feed pellet 1000 g

2.6. Water Quality Management

Water quality management involves siphoning and changing the water in the rearing medium. Siphoning is performed once daily at 7:00 a.m. before feeding the fish. A 50–60% change of the rearing medium is performed daily (Surnawati et al., 2020).

2.7. Absolute Length and Weight Growth

Absolute length and weight measurements are used to assess the actual physical changes in fish during the treatment period. The absolute growth in length and weight of the white snapper during the study period was calculated using Equations 1 and 2, respectively (Windarto, 2019).

$$L = Lt - Lo \quad (1)$$

where L (cm) is the absolute length growth, while Lt (cm) and Lo (cm) are the average lengths of white snapper fry at the end and beginning of cultivation, respectively.

$$W = Wt - Wo \quad (2)$$

where W (g) is the absolute weight gain, and Wt (g) and Wo (g) are the average weights of white snapper fry at the end and beginning of cultivation, respectively.

2.8. Specific Growth Rate (SGR)

The specific growth rate (SGR) was determined using Equation 3 (Jaya et al., 2013) as follows.

$$SGR = \frac{\ln Wt - \ln Wo}{T} 100\% \quad (3)$$

where SGR (% day⁻¹) is the specific growth rate, Wt (g) and Wo (g) are the average weights of the fish at the end and beginning of the study, respectively, and T (days) is the duration of the culture period.

2.9. Survival Rate (SR)

The fish survival rate was calculated by comparing the number of fish at the end of the study with those released at the beginning, using Equation 4 (Effendie, 2002) as follows.

$$SR = \left[\frac{Nt}{No} \right] \times 100\% \quad (4)$$

where SR (%) is the survival rate, and N_t and N_o are the number of fish at the end and beginning of the study, respectively.

2.10. Feed Conversion Ratio (FCR)

The feed conversion ratio (FCR) was calculated using Equation 5 (Pratama et al., 2021) as follows.

$$FCR = \frac{F}{(W_t + D) - W_o} \quad (5)$$

where FCR is the feed conversion ratio, F (g) is the total amount of feed given, W_t (g) and W_o (g) are the total fish biomass at the end and beginning of the culture period, respectively, and D (g) is the total biomass of the dead fish.

2.11. Water Quality

Water quality parameters were measured twice, at the beginning and at the end. The parameters measured in this study included temperature, pH, and dissolved oxygen (DO). A Horiba U-10 thermometer (Kyoto, Japan) is used to measure temperature. To measure pH using a digital pH meter (pH meter Horiba U-10, Kyoto, Japan), DO measurements were performed using a DO meter (DO meter Horiba U-54, Kyoto, Japan).

2.12. Data Analysis

The FCR data were then statistically analyzed using Analysis of Variance (ANOVA) at a 95% confidence level. If the statistical analysis shows a significant effect, the Tukey Post Hoc test is conducted to identify the best treatment. Data analysis was conducted using the statistical software SPSS (Statistical Package for the Social Sciences).

3. Results and Discussion

3.1. Absolute Length Growth

The length of white snapper increased every week, with the highest increase in length at a concentration of 5% (P2), followed by a concentration of 7.5% (P3) and a concentration of 2.5% (P1).

3.2. Absolute Weight Growth

The results showed that the average absolute weight of white snapper in the control group was 5.59 g, while in P1 (8.36 g), P2 (9.28 g), and P3 (8.32 g). This indicates that all treatment groups had higher absolute weights than the control. Based on these treatments, P2 had the highest average value, followed by P1 and P3, whose values were not much different. The results of the statistical analysis are shown in **Table 2**.

Table 2. Absolute weight of white snapper supplemented with moringa leaf extract

Treatment	Weight (g)
Control	5.59 ± 0.83 ^b
P1	8.36 ± 1.82 ^a
P2	9.28 ± 0.30 ^a
P3	8.32 ± 1.66 ^a

Notes: Values are presented as mean ± standard deviation. Different superscript letters within the same column indicate significant differences among treatments at $p < 0.05$, while the same letters indicate no significant difference.

3.3. Daily Specific Growth Rate (SGR)

The results showed that group P1 (4.79%) had the highest average SGR value and was significantly different from the control (3.46%). Meanwhile, P2 (4.56%) and P3 (4.59%) also showed higher values than the control, but the differences were not statistically significant. Thus, P1 was proven to effectively increase fish growth compared to the control, while P2 and P3 had a moderate effect (**Table 3**).

Table 3. Specific growth rate of white snapper supplemented with moringa leaf extract

Treatment	Specific growth rate (% day ⁻¹)
Control	3.46 ± 0.34 ^b
P1	4.79 ± 0.11 ^a
P2	4.56 ± 0.43 ^{ab}
P3	4.59 ± 0.47 ^{ab}

Notes: Values are presented as mean ± standard deviation. Different superscript letters within the same column indicate significant differences among treatments at $p < 0.05$, while the same letters indicate no significant difference.

3.4. Survival Rate (SR)

The results were relatively high, with values exceeding 90% for all treatments, indicating good rearing conditions and that the treatments did not adversely affect fish health. White snapper fish fed with commercial fish pellets supplemented with Moringa leaf extract showed good survival of white snapper fish—at 100% compared to the control (90%). The one-way ANOVA indicated a significant difference ($p < 0.05$). Furthermore, the Tukey HSD test showed that the average SR of white snapper in P1, P2, and P3 was significantly higher ($p < 0.05$) than that of the control. There was no significant difference between the three treatments, indicating that all treatments had the same positive effect on increasing the SR of white snapper (**Table 4**).

Table 4. Survival rate of white snapper supplemented with moringa leaf extract

Treatment	Survival rate (%)
Control	11.74 ± 2.92 ^b
P1	23.72 ± 0.35 ^a
P2	23.72 ± 0.35 ^a
P3	23.72 ± 0.35 ^a

Notes: Values are presented as mean ± standard deviation. Different superscript letters within the same column indicate significant differences among treatments at $p < 0.05$, while the same letters indicate no significant difference.

3.5. Feed Conversion Ratio (FCR)

The FCR value is fairly high, above 2%. This indicates that there is no significant difference between treatment groups (**Table 5**).

Table 5. FCR of white snapper supplemented with moringa leaf extract

Treatment	Feed conversion ratio
Control	3.13 ± 0.62 ^b
P1	2.58 ± 0.20 ^a
P2	2.63 ± 0.16 ^a
P3	2.75 ± 0.37 ^a

Notes: Values are presented as mean ± standard deviation. Different superscript letters within the same column indicate significant differences among treatments at $p < 0.05$, while the same letters indicate no significant difference.

3.6. Water Quality

Water quality measurements and observations on white snapper fry were conducted three times during the rearing period (**Table 4**). Temperature measurements during the study period ranged from 28°C to 30°C, pH from 7.27 to 8.72, and dissolved oxygen (DO) from 4.33 to 5.92. Based on Government Regulation Number 22 of 2021 concerning Implementation of Environmental Protection and Management related to marine water quality standards, these values are still considered good for white snapper cultivation (**Table 6**).

Fish growth depends on the amount of food ingested. It is influenced by internal factors as well as external factors such as the physical, chemical, and biological conditions of the water. Food and temperature are the main factors (Prihadi 2011). ANOVA results showed that adding moringa leaf extract to the feed did not significantly affect barramundi growth, possibly due to variability in the data or inadequate sampling.

Table 6. Water quality parameters measured during the culture period

Treatment	Parameter		
	Temperatur (°C)	pH	Dissolved oxygen (mg/L)
Control	28.2–30	7.27–8.05	5.60–5.92
P1	28.2–30	7.43–8.27	4.33–5.60
P2	28.3–30	7.48–8.02	5.03–5.67
P3	28.0–30	7.61–7.72	5.46–5.71
Quality Standard	28.0–32	7.00–8.50	> 5

The effectiveness of supplemental feeds, such as moringa leaf extract, depends heavily on the dosage. If the concentration is incorrect or too high, the extract can actually inhibit growth by being toxic, disrupting cell metabolism, or inhibiting enzyme activity due to excessive flavonoid content (Adelia and Sunarti, 2024). Handayani and Widodo (2010) and Panda et al. (2025) state that the increase in body weight of fish fed all test feeds indicates that the feed provided is consumable and utilized by the fish for body maintenance. Based on the data obtained, the weight of white snapper increased. This is evident in the control treatment, which showed the lowest average growth of 5.34 g, while the P2 treatment achieved the highest weight of 7.13 g. It was suspected that this dose was optimal. P3 followed this at 6.56 g and P1 at 6.47 g. This is in line with research across several literatures, including studies on patin and tilapia fry treated with moringa leaf flour or extract added to commercial feed, which generally increase fish weight (Fahmi et al., 2025; Gazali, 2020; Islam et al., 2024).

Naria et al. (2022) and Faisal et al (2024) explained that moringa leaf extract has the potential to increase daily growth rate because it contains several nutrients, such as protein, amino acids, and antioxidants, which can improve feed quality and enhance metabolic processes in fish. Kelen et al. (2022) also explained that optimal concentrations can positively affect the digestive system, increasing nutrient absorption capacity and accelerating growth. Commercial feed enriched with moringa leaf extract provides vitamins, minerals, and bioactive compounds, including antioxidants and flavonoids, that support nutrient absorption, energy metabolism, protein synthesis, and tissue and muscle growth in fish. These compounds also increase endurance, thereby maintaining good physiological condition and more efficient growth in fish, as reflected in an increase in the specific growth rate (SGR) (Pirmansyah et al., 2024; Gaber et al., 2025).

The data obtained showed that the treatment of moringa leaf extract in commercial feed can indirectly increase the potential for survival rate (SR). SR values in groups P1, P2, and P3 are up to 100%, while the control is only 90%. This shows that all treatments, especially those using moringa leaf extract, may maintain optimal fish survival rates without causing significant mortality. According to Islam (2024), Moringa leaf extract contains bioactive compounds, including flavonoids, phenols, vitamin C, and tannins, that function as antibacterials, anti-inflammatories, and antioxidants. These compounds help increase fish's resistance to infection and environmental stress. Several studies have shown that moringa leaf supplementation can improve the survival and immune function of various fish species, including tilapia and catfish, thereby reducing mortality. Furthermore, Rosyadi and Hadi (2023) stated that flavonoids and phenolic compounds in moringa leaf extract act as antibacterials, effective against pathogens in fish farming. By reducing the risk of infection, fish can survive optimally. Furthermore, this extract acts as an immunostimulant, boosting the fish's immune system.

According to Destian et al. (2016), an FCR value above 2% indicates suboptimal feed utilization efficiency, as fish require large amounts of feed to gain weight. This can be caused by low-quality feed or overfeeding, leading to inadequate nutrient absorption and significant feed waste. Another possible reason is the physiological factors in the fish. Fish physiology, such as the digestive system, metabolic processes, and immune system, plays a role in determining the efficiency with which feed is absorbed and converted into energy for growth (Saleh et al., 2025; Ridwan et al., 2020). Carnivorous fish, such as this White Snapper, have digestive systems designed to process animal protein, so they are less efficient at processing plant-based feedstuffs like Moringa. This may be due to a lack of appropriate digestive enzymes to process plant components, such as cellulose and lignin, an incompatibility of the anatomical structure of the digestive tract to process plant feed, or an imbalance in the nutritional composition of plant feed with the nutritional needs of the fish (Santika et al., 2021).

Good water quality is crucial for the success of white snapper cultivation. Measurements over 28 days showed that temperature, pH, and DO were within the normal range, as defined by Law Number

22 of 2001 (Aulia, 2020). The optimal seawater temperature for white snapper is 25–31°C, as temperature affects dissolved oxygen levels and fish metabolism. Increasing the temperature can decrease dissolved oxygen levels and disrupt fish metabolism. Environmental parameters are crucial in the cultivation process. Environmental parameter measurements are conducted to assess water quality based on its physical and chemical properties (Azhari and Tomaso, 2018). Water quality measurements are crucial in fish cultivation, as they significantly affect fish growth and survival.

4. Conclusion

The incorporation of moringa leaf extract into commercial feed influenced the growth performance and survival of white snapper under the tested conditions. Fish fed moringa-supplemented diets showed higher growth values than the control, with the highest weight gain at 5% inclusion and the highest specific growth rate at 2.5%. Survival rates reached 100% in all supplemented treatments, exceeding those of the control group. Feed conversion ratios remained above optimal levels across treatments, indicating limited feed utilization efficiency. These results suggest that moringa leaf extract has potential as a supplementary feed ingredient, and further research is required to determine optimal inclusion levels and improve feed efficiency, particularly for carnivorous fish species.

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Conflict of Interest: This research was conducted independently, and no conflicts of interest are declared.

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