

COMBINATION OF SEAWEED MEAL (*GRACILARIA VERRUCOSA*) AND MORINGA LEAF MEAL (*MORINGA OLEIFERA*) IN DIETS ON DIGESTIBILITY, INTESTINAL HISTOLOGY, BLOOD PROFILE AND GROWTH OF SALINE NILE TILAPIA (*OREOCHROMIS NILOTICUS*)

Wellem Henrik Muskita ^{1,*}, Zaim Bahtiar ², Ruslaini ¹, Indriyani Nur ¹, Agus Kurnia ¹, Muhaimin Hamzah ¹, La Ode Baytul Abidin ¹, Hamsah ³, and La Ode Muh. Munadi ⁴

¹Department of Aquaculture, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia

²Student of the Department of Aquaculture, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia

³Department of Aquaculture, Universitas Muhammadiyah Makassar, Makassar, South Sulawesi, Indonesia

⁴Department of Animal Science, Faculty of Animal Science, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia

*Corresponding author: wellemhenrikmuskita@uho.ac.id

ABSTRACT

Saline Nile tilapia (*Oreochromis niloticus*) has considerable aquaculture potential in coastal and brackish-water areas; however, efficient production requires affordable, nutritious, and sustainable feeds. This study evaluated seaweed meal (*Gracilaria verrucosa*) and moringa leaf meal (*Moringa oleifera*), supplied individually or in combination, for their effects on protein and total digestibility, intestinal histomorphology, hematological indices, organ indices, and growth. A completely randomized design included four treatments with three replicate tanks per treatment: A, 5% moringa leaf meal + 5% seaweed meal; B, 10% seaweed meal; C, 10% moringa leaf meal; and D, commercial feed. Fish (initial body weight, 4.26±0.87 g) were reared for 45 days at 13-15 ppt. Measured outcomes included protein digestibility, total digestibility, absolute weight gain, villus height and width, intestine somatic index, hepatosomatic index, total erythrocyte and leukocyte counts, and water quality. Diet significantly affected protein digestibility, total digestibility, and absolute weight gain ($P<0.05$). Commercial feed produced the highest values for these three outcomes. Among the experimental diets, treatment C produced the highest total digestibility, absolute weight gain, villus width, and erythrocyte and leukocyte counts. Thus, at the tested inclusion levels, 10% moringa leaf meal was more promising than 10% seaweed meal or their 5%+5% combination. Pretreatment, including fermentation, warrants evaluation to reduce the effects of fiber, ash, and antinutritional compounds.

Keywords: Digestibility, *Gracilaria verrucosa*, Intestinal histology, *Moringa oleifera*, *Oreochromis niloticus*.

Article History: ABR-26-248 || Received: 21-Jun-2026 || Revised: 11-Sep-2026 || Accepted: 13-Sep-2026 || Published Online: 03-Oct-2026

This is an open-access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. INTRODUCTION

Aquaculture has become a strategic food-production system because it provides animal protein, employment, and income for coastal and inland communities. Global fisheries and aquaculture production continue to increase, and aquatic foods are now recognized as important components of food security and nutrition. However, aquaculture expansion also increases pressure on feed-ingredient supplies, particularly conventional marine-derived protein and lipid sources. Feed quality, feeding management, and the cost of formulated diets remain central constraints in farm productivity, intensifying research into feeds that are efficient, affordable, and environmentally responsible (Tacon & Metian, 2015; Hua et al., 2019; Boyd et al., 2020; Naylor et al., 2021; Ikeogu et al., 2022; FAO, 2024).

Current aquaculture nutrition research shows a clear shift from fishmeal-based feeds toward formulations incorporating plant ingredients, local resources, agro-industrial by-products, insect meals, microalgae, macroalgae, fermented materials, and functional additives. This shift is driven by feed cost and by the need to improve nutrient efficiency, intestinal health, immune responses, and fish resilience to environmental stress. Alternative protein sources and probiotic or symbiotic strategies may also influence intestinal microbiota,

Citation: Muskita, W.H., Bahtiar, Z., Ruslaini, Nur, I., Kurnia, A., Hamzah, M., Abidin, L.O.B., Hamsah, & Munadi, L.O.M. (2026). Combination of seaweed meal (*Gracilaria verrucosa*) and moringa leaf meal (*Moringa oleifera*) in diets on digestibility, intestinal histology, blood profile, and growth of Nile tilapia (*Oreochromis niloticus*). *Agrobiological Records*, 26, 59-68. <https://doi.org/10.47278/journal.abr/2026.083>

mucosal integrity, stress responses, immunity, and welfare, making ingredient evaluation broader than growth alone (Gatlin et al., 2007; Glencross, 2020; Aragão et al., 2022; Usman et al., 2024; Herawati et al., 2026). Nevertheless, plant and algal ingredients often contain crude fiber, inorganic minerals, complex polysaccharides, and antinutritional compounds that can limit digestibility and protein utilization (Francis et al., 2001; Mmanda et al., 2020; Hussain et al., 2024).

Nile tilapia (*O. niloticus*) is a major global aquaculture commodity because of its rapid growth, broad environmental tolerance, and capacity to utilize diverse feed ingredients. Developing saline-tolerant Nile tilapia is particularly important because it can expand fish production in coastal areas, marginal ponds, and brackish-water resources. Nile tilapia can survive and grow at suitable salinity levels after acclimation, but its physiological responses remain strongly influenced by feed quality, osmoregulatory efficiency, and the availability of digestible energy and protein. Studies in brackish water and floating net cages further show that diet formulation and functional supplementation can influence tilapia growth, feed utilization, hematology, innate immunity, and gut health (Thomas et al., 2021; Rahmi et al., 2024; Rahmi et al., 2025; Herawati et al., 2026; Masriah et al., 2026).

Red seaweeds of the genus Gracilariaceae have attracted attention as functional feed ingredients because they contain minerals, fiber, sulfated polysaccharides, pigments, and bioactive compounds that may modulate intestinal microbial communities and barrier function, and support immune responses (Wan et al., 2019; Siddik et al., 2023). However, seaweed inclusion can reduce palatability, alter intestinal morphology, or suppress growth when fiber and ash contents are excessive. Responses vary with the seaweed species, processing method, fish species, and dietary inclusion level (Azaza et al., 2008; Silva et al., 2015; Ashour et al., 2020; Bakky et al., 2023; Weththasinghe et al., 2026). Therefore, seaweed should be evaluated as both a nutrient source and a functional ingredient requiring an appropriate inclusion level and processing method.

Moringa leaves (*M. oleifera*) also have strong potential as feed ingredients and functional additives because they contain protein, vitamins, minerals, flavonoids, phenolics, and natural antioxidants (Saini et al., 2016). Dietary studies indicate that moringa-based ingredients at appropriate levels can improve growth, feed utilization, hematological status, innate immunity, and resistance to infection in aquatic animals (Afuang et al., 2003; Richter et al., 2003; Kamble et al., 2024; Nassar et al., 2024; Saleh et al., 2025). However, unprocessed leaf meal may contain fiber and secondary metabolites that limit digestibility at high inclusion levels, so processing and ingredient combinations require careful evaluation (Jiang et al., 2023).

This study's novelty lies in its integrated evaluation of *G. verrucosa* seaweed meal and *M. oleifera* leaf meal in diets for saline Nile tilapia. The evaluation was not limited to growth but also included protein digestibility, total digestibility, intestinal histology, blood profile, intestine somatic index, and hepatosomatic index. This approach is relevant internationally because it addresses sustainable feed formulation using local resources while considering fish physiological responses under brackish conditions. Recent evaluations of mealworm meal and aquatic plant biomass similarly demonstrate that sustainable ingredients should be assessed by feed utilization and biological performance rather than by ingredient availability alone (Silva et al., 2015; Naylor et al., 2021; Hussain et al., 2024; Herawati et al., 2026; Rakhmonov et al., 2026).

2. MATERIALS AND METHODS

2.1. Bioethical Statement

The Ethical Committee for Research of the Institution of Research and Community Service, Halu Oleo University, Kendari, Indonesia, approved the animal-use protocol (approval No. 1421/UN29.20.1.2/PG/2025; approved on July 7, 2025). The approval was issued for the research protocol entitled "Combination of Seaweed Flour (*G. verrucosa*) and Moringa Leaf Flour (*M. oleifera*) in Feed on Digestibility Level, Intestinal Histology, Blood Picture, and Growth of Tilapia (*O. niloticus*). Fish handling minimized stress during acclimation, feeding, sampling, and blood collection.

2.2. Study Time and Location

The study was conducted from April to July 2025 at the Laboratory of Aquaculture, Hatchery, and Fisheries Production, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia. Proximate analysis and chromium analysis of feed and feces were conducted at the Fish Nutrition Laboratory, Department of Aquaculture, Faculty of Fisheries and Marine Sciences, IPB University, Bogor, Indonesia. Intestinal histology was examined at the Center for Veterinary Assembly and Modernization, Bogor, Indonesia. Blood profile analysis was performed at the Laboratory of Aquaculture, Hatchery, and Fisheries Production, Halu Oleo University. Using several laboratories ensured that nutrient, digestibility, histological, and hematological indicators were measured using procedures appropriate for fish nutrition studies (Mmanda et al., 2020; Kamble et al., 2024).

Citation: Muskita, W.H., Bahtiar, Z., Ruslaini, Nur, I., Kurnia, A., Hamzah, M., Abidin, L.O.B., Hamsah, & Munadi, L.O.M. (2026). Combination of seaweed meal (*Gracilaria verrucosa*) and moringa leaf meal (*Moringa oleifera*) in diets on digestibility, intestinal histology, blood profile, and growth of Nile tilapia (*Oreochromis niloticus*). *Agrobiological Records*, 26, 59-68. <https://doi.org/10.47278/journal.abr/2026.083>

2.3. Experimental Design

The study used a completely randomized design with four dietary treatments and three replicates. The treatments were A: 5% moringa leaf meal + 5% seaweed meal; B: 10% seaweed meal + 0% moringa leaf meal; C: 0% seaweed meal + 10% moringa leaf meal; and D: commercial feed as a practical control. This design compared the effects of alternative ingredients, used individually and in combination, on the nutritional and physiological responses of saline Nile tilapia.

2.4. Diet Formulation and Preparation

The experimental diets were prepared as pellets from scad fish meal, shrimp head meal, soybean meal, *G. verrucosa* seaweed meal, *M. oleifera* leaf meal, corn meal, rice bran, sago flour, tapioca flour, fish oil, squid oil, corn oil, and premix. Table 1 presents the ingredient proportions (g/100 g feed). We cleaned, dried, milled, and visually checked the seaweed and moringa materials against their source descriptions before preparing the diets. We ground ingredients, weighed them according to the formulation, and mixed them progressively from the lowest to the highest inclusion level until homogeneous. Water was added to obtain a workable dough, which was pelleted to a size suitable for juvenile tilapia, dried, and stored in sealed plastic containers until use. These procedures were applied consistently across experimental diets to minimize variation in ingredient distribution and feed handling (Tacon & Metian, 2015; Glencross, 2020; Ikeogu et al., 2022; Hussain et al., 2024; Herawati et al., 2026).

Table 1: Experimental diet formulation (g/100 g feed)

Feed ingredient	A	B	C
Scad fish meal	20	20	20
Shrimp head meal	20	20	20
Soybean meal	20	20	20
Seaweed meal (<i>G. verrucosa</i>)	5	10	0
Moringa leaf meal (<i>M. oleifera</i>)	5	0	10
Corn meal	10	10	10
Rice bran	7	8	8
Sago flour	4	4	4
Tapioca flour	7	7	7
Fish oil	0.5	0.5	0.5
Squid oil	0.5	0.5	0.5
Corn oil	0.5	0.5	0.5
Top mix	0.5	0.5	0.5
Total	100	100	100

Note: A = 5% MLM + 5% SM; B = 10% SM + 0% MLM; C = 0% SM + 10% MLM. MLM = moringa leaf meal; SM = seaweed meal.

2.5. Rearing Units and Test Fish

The rearing system comprised 12 containers (60×40×40 cm), each supplied with continuous aeration. Saline Nile tilapia (*O. niloticus*; initial body weight, 4.26±0.87 g per fish) were obtained from a community hatchery in Kendari City. Fish were acclimated for 15 days, during which salinity was increased by 1 ppt/day to 15 ppt. We maintained the containers under the prevailing laboratory light-dark cycle and monitored water temperature twice daily; the observed temperature range is reported in Table 6. We used gradual acclimation because salinity changes affect osmoregulation, feed intake, and energy allocation in tilapia (Thomas et al., 2021).

2.6. Fish Rearing

After acclimatization, fish were stocked into the 12 containers at a density of 10 fish per container. Fish were fasted for 24 hours before the feeding trial to reduce residual feed in the digestive tract. The rearing period lasted 45 days. Feed was provided twice daily at 08:00 and 16:00 Central Indonesia Time, ad libitum. A 45-day feeding period enabled observation of growth, digestibility, blood profile, and intestinal tissue responses within a single cycle of functional feed evaluation (Kamble et al., 2024; Nassar et al., 2024).

2.7. Digestibility Test

We evaluated digestibility by adding 0.5% chromium oxide (Cr_2O_3) to the feed as an inert marker. We began fecal collection after fish had consumed the experimental diets for three days. We collected feces by siphoning approximately three to four hours after feeding, placed them in bottles, froze them, and dried them before proximate and Cr_2O_3 analyses. We calculated protein digestibility and total digestibility using an indirect-marker method commonly applied in fish-feed ingredient studies (Köprücü & Özdemir, 2005; Mmanda et al., 2020; Glencross, 2020). Digestibility and feed-efficiency measurements are particularly important when unconventional or fermented ingredients replace conventional feed materials (Surianti et al., 2026; Herawati et al., 2026).

2.8. Intestinal Histology

Intestinal histology was examined after 45 days of rearing. Fish were dissected to collect intestinal tissue, and samples were placed in microtubes containing 10% formalin. Samples were packed in a cooled container and sent for histological preparation and examination. We measured villus height and width because intestinal mucosal structure is associated with absorptive surface area and nutrient utilization (Aanyu et al., 2014; Silva et al., 2015; Ramos et al., 2017; Rahmi et al., 2025).

Citation: Muskita, W.H., Bahtiar, Z., Ruslaini, Nur, I., Kurnia, A., Hamzah, M., Abidin, L.O.B., Hamsah, & Munadi, L.O.M. (2026). Combination of seaweed meal (*Gracilaria verrucosa*) and moringa leaf meal (*Moringa oleifera*) in diets on digestibility, intestinal histology, blood profile, and growth of Nile tilapia (*Oreochromis niloticus*). *Agrobiological Records*, 26, 59-68. <https://doi.org/10.47278/journal.abr/2026.083>

2.9. Blood Profile, Organ Indices and Growth

We measured blood profiles at the beginning and end of the study by counting total erythrocytes and leukocytes using a hemocytometer. Blood was collected from the caudal vein using a syringe containing an anticoagulant. We calculated the intestine somatic index and hepatosomatic index as ratios of organ weight to body weight. We calculated absolute growth as the difference between final and initial average body weight. Hematological parameters and organ indices were used as indicators of physiological condition, metabolism, and fish health in response to functional diets (Kamble et al., 2024; Nassar et al., 2024; Rahmi et al., 2024; Rahmi et al., 2025; Villasante et al., 2025).

2.10. Water Quality

We measured temperature and salinity daily in the morning and afternoon, while measuring pH and dissolved oxygen at 15-day intervals. These variables were summarized descriptively as environmental support data.

2.11. Statistical Analysis

Each tank was treated as the experimental unit ($n = 3$ tanks per dietary treatment). Data were summarized as mean $\pm$ standard deviation. Protein digestibility, total digestibility, absolute weight gain, intestinal morphometry, organ indices, and hematological variables were evaluated by one-way analysis of variance at $\alpha=0.05$. When the overall treatment effect was significant, Duncan's multiple range test was used for pairwise comparison. Water-quality data were summarized descriptively. We defined statistical significance as $P<0.05$.

We measured temperature and salinity daily in the morning and afternoon, while measuring pH and dissolved oxygen every 15 days. We analyzed data on digestibility, growth, histology, organ indices, and blood profile using analysis of variance at a 95% confidence level. When significant differences were detected, we applied Duncan's multiple range test. Water quality data were analyzed descriptively because they were used as supporting environmental data.

3. RESULTS

3.1. Protein Digestibility, Total Digestibility and Growth

Treatment D (commercial feed) had the highest protein digestibility ($69.87\pm1.42\%$), while treatment A had the lowest ($46.37\pm3.09\%$). Dietary treatment significantly affected protein digestibility, total digestibility, and absolute weight gain ($P<0.05$; Table 2). Commercial feed (treatment D) produced the highest protein digestibility ($69.87 \pm 1.42\%$), total digestibility ($60.47\pm0.22\%$), and absolute weight gain (15.35 ± 0.84 g). Among the alternative diets, treatments B and C had similar protein digestibility values ($56.26\pm3.73\%$ and $55.72\pm1.13\%$, respectively), whereas treatment C produced the highest total digestibility ($42.19\pm0.47\%$) and absolute weight gain (12.36 ± 1.13 g). Treatment A produced the lowest values for all three outcomes.

Table 2: Protein digestibility, total digestibility, and absolute growth of saline Nile tilapia after 45 days of rearing

Treatment	Protein digestibility (%)	Total digestibility (%)	Absolute growth (g)
A	46.37 ± 3.09^a	29.45 ± 4.22^a	9.60 ± 0.60^a
B	56.26 ± 3.73^b	39.12 ± 5.74^{ab}	11.16 ± 0.95^{ab}
C	55.72 ± 1.13^b	42.19 ± 0.47^b	12.36 ± 1.13^b
D	69.87 ± 1.42^c	60.47 ± 0.22^c	15.35 ± 0.84^c

Note: Different superscript letters in the same column indicate significant differences based on Duncan's multiple range test ($P<0.05$).

in treatment B (356.91 ± 135.96 μm), followed by treatments A, D, and C. Initial villus width was 126.91 ± 63.02 μm ; the numerically greatest final villus width occurred in treatment C (186.47 ± 55.84 μm), followed by treatments D, B, and A. These comparisons are descriptive because the table does not contain inferential statistical groupings.

Table 3: Intestinal villus morphometry of saline Nile tilapia

Parameter	Initial	A	B	C	D
Villus height (μm)	139.02 ± 16.96	352.37 ± 129.79	356.91 ± 135.96	161.12 ± 24.39	264.44 ± 70.74
Villus width (μm)	126.91 ± 63.02	87.58 ± 36.24	146.59 ± 53.31	186.47 ± 55.84	151.53 ± 54.56

3.3. Intestine Somatic Index and Hepatosomatic Index

The intestine somatic index (ISI) and hepatosomatic index (HSI) are presented in Table 4. ISI increased from an initial value of 4.41 ± 1.03 to 6.83 ± 0.70 , 7.92 ± 0.36 , 8.26 ± 0.68 , and $9.24\pm1.27\%$ in treatments A, B, C, and D, respectively. HSI increased from $0.19\pm0.11\%$ initially to 0.42 ± 0.04 , 0.51 ± 0.14 , 0.57 ± 0.15 , and $0.70\pm0.16\%$ in treatments A, B, C and D, respectively. These numerical patterns indicate diet-associated differences in digestive and hepatic indices.

Citation: Muskita, W.H., Bahtiar, Z., Ruslaini, Nur, I., Kurnia, A., Hamzah, M., Abidin, L.O.B., Hamsah, & Munadi, L.O.M. (2026). Combination of seaweed meal (*Gracilaria verrucosa*) and moringa leaf meal (*Moringa oleifera*) in diets on digestibility, intestinal histology, blood profile, and growth of Nile tilapia (*Oreochromis niloticus*). *Agrobiological Records*, 26, 59-68. <https://doi.org/10.47278/journal.abr/2026.083>

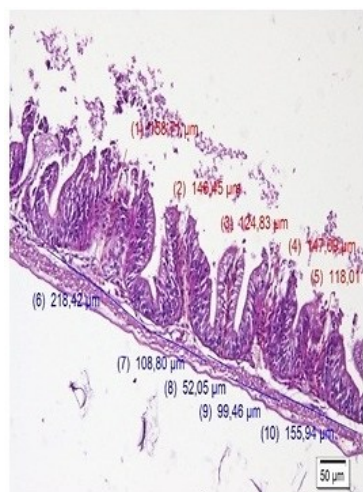


Fig. 1: Initial sample (OZ). Height and width of intestinal mucosal villi. H&E, x200.



Fig. 1a: Sample AZ. Height and width of intestinal mucosal villi. H&E, x200.

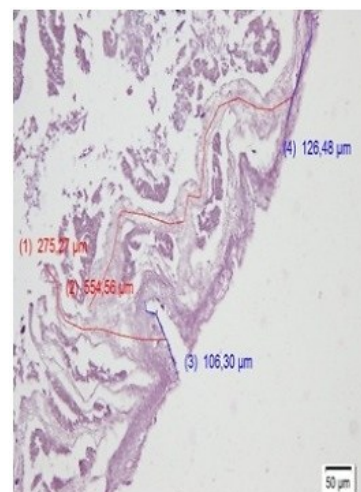


Fig. 1b: Sample AZ. Height and width of intestinal mucosal villi. H&E, x200.

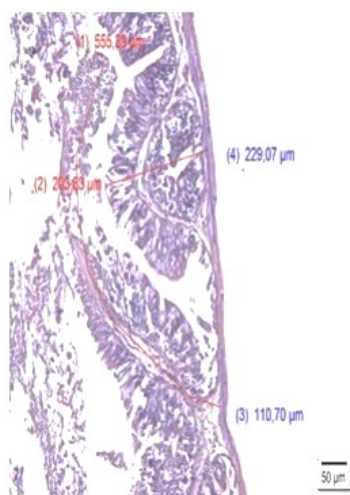


Fig. 2a: Sample BZ. Height and width of intestinal mucosal villi. H&E, x200.

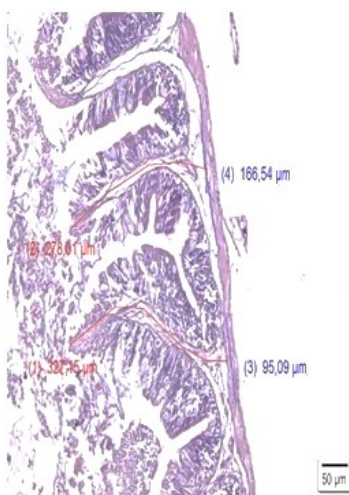


Fig. 2b: Sample BZ. Height and width of intestinal mucosal villi. H&E, x200.

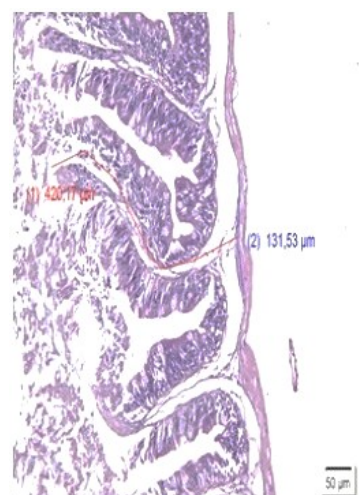


Fig. 2c: Sample BZ. Height and width of intestinal mucosal villi. H&E, x200.



Fig. 3a: Sample CZ. Height and width of intestinal mucosal villi. H&E, x200.

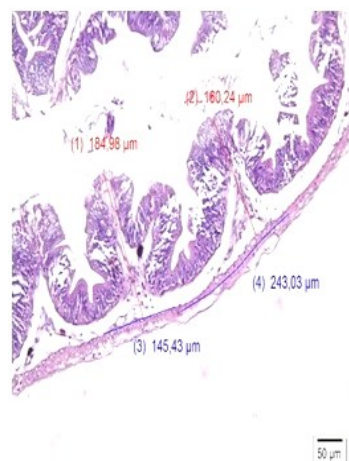


Fig. 3b: Sample CZ. Height and width of intestinal mucosal villi. H&E, x200.

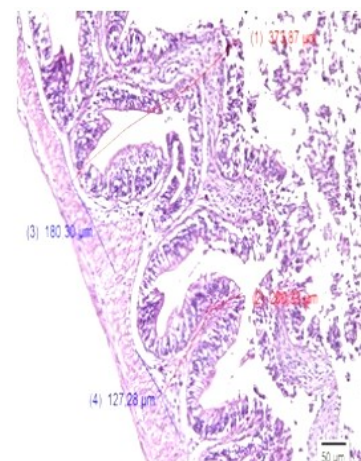


Fig. 4a: Sample DZ. Height and width of intestinal mucosal villi. H&E, x200.

Citation: Muskita, W.H., Bahtiar, Z., Ruslaini, Nur, I., Kurnia, A., Hamzah, M., Abidin, L.O.B., Hamsah, & Munadi, L.O.M. (2026). Combination of seaweed meal (*Gracilaria verrucosa*) and moringa leaf meal (*Moringa oleifera*) in diets on digestibility, intestinal histology, blood profile, and growth of Nile tilapia (*Oreochromis niloticus*). *Agrobiological Records*, 26, 59-68. <https://doi.org/10.47278/journal.abr/2026.083>

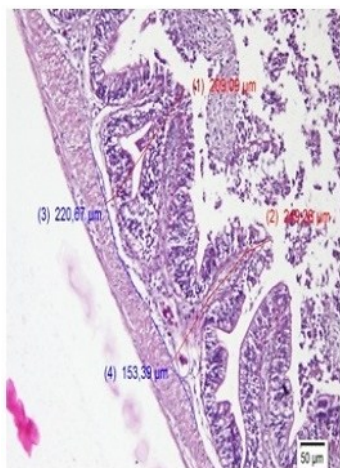


Fig. 4b: Sample DZ. Height and width of intestinal mucosal villi. H&E, x200.

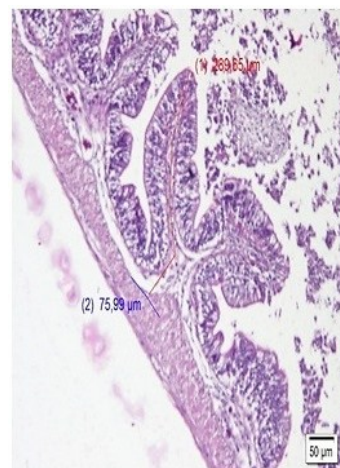


Fig. 4c: Sample DZ. Height and width of intestinal mucosal villi. H&E, x200.

Table 4: Intestine somatic index (ISI) and hepatosomatic index (HSI) of saline Nile tilapia

Treatment	ISI (%)	HSI (%)
Initial	4.41±1.03	0.19±0.11
A	6.83±0.70	0.42±0.04
B	7.92±0.36	0.51±0.14
C	8.26±0.68	0.57±0.15
D	9.24±1.27	0.70±0.16

Table 5: Total erythrocytes and leukocytes of saline Nile tilapia

Treatment	Total erythrocytes ($\times 10^6$ cells/mm ³)	Total leukocytes ($\times 10^4$ cells/mm ³)
Initial	0.40±0.00	0.03±0.00
A	3.36±0.64	67.41±6.39
B	2.72±0.40	71.06±12.44
C	5.58±0.30	109.67±35.55
D	5.87±0.43	127.99±8.76

Table 6: Water quality during the rearing period

Parameter	Value
Temperature (°C)	26-28
pH	7.3-8.1
Dissolved oxygen (mg/L)	5.4-6.7
Salinity (ppt)	13-15

3.4. Blood Profile

Total erythrocyte and leukocyte counts are shown in Table 5. Relative to the initial values ($0.40 \pm 0.00 \times 10^6$ erythrocytes/mm³ and $0.03 \pm 0.00 \times 10^4$ leukocytes/mm³), both counts were numerically higher at day 45 in every treatment. Treatment D had the highest final erythrocyte and leukocyte counts, followed by treatment C. Treatments A and B had lower final counts than treatments C and D. These comparisons are descriptive because inferential statistical groupings are not provided in Table 5.

3.5. Water Quality

Table 6 presents water-quality ranges. Temperature was 26-28°C, pH was 7.3-8.1, dissolved oxygen was 5.4-6.7 mg/L, and salinity was 13-15 ppt. These conditions remained within the intended rearing range throughout the trial; consequently, the observed biological responses were interpreted primarily in relation to dietary treatment.

4. DISCUSSION

This study showed that commercial feed produced the highest protein digestibility, total digestibility, and growth values. This result is reasonable because commercial feeds are generally formulated with stable balances of protein, energy, lipids, minerals, vitamins, and amino acids. In Nile tilapia, protein and energy digestibility are key determinants of feed-use efficiency and tissue deposition. Ingredients with highly digestible protein and balanced amino-acid profiles are generally used more efficiently than alternative ingredients containing high levels of fiber or indigestible fractions (Köprücü & Özdemir, 2005; Glencross, 2020; Mmanda et al., 2020; Ikeogu et al., 2022; Herawati et al., 2026).

Among the alternative diets, treatment C, containing 10% moringa leaf meal, produced the best responses in total digestibility, absolute growth, villus width, and erythrocyte and leukocyte profiles. This response supports the functional value of moringa, which provides protein, minerals, vitamins, flavonoids, and phenolics. Studies in aquatic animals show that appropriately processed or dosed moringa ingredients can improve growth, feed utilization, hematological profiles, innate immunity, and disease resistance (Afuang et al., 2003; Richter et al., 2003; Kamble et al., 2024; Nassar et al., 2024; Saleh et al., 2025).

However, protein digestibility in treatment C remained lower than that in the commercial-feed treatment. Although moringa leaves have potential as an alternative feed ingredient, unprocessed leaf meal may still contain

Citation: Muskita, W.H., Bahtiar, Z., Ruslaini, Nur, I., Kurnia, A., Hamzah, M., Abidin, L.O.B., Hamsah, & Munadi, L.O.M. (2026). Combination of seaweed meal (*Gracilaria verrucosa*) and moringa leaf meal (*Moringa oleifera*) in diets on digestibility, intestinal histology, blood profile, and growth of Nile tilapia (*Oreochromis niloticus*). *Agrobiological Records*, 26, 59-68. <https://doi.org/10.47278/journal.abr/2026.083>

fiber and antinutritional compounds that limit protein breakdown and absorption. Plant ingredients often require pretreatments such as fermentation, heating, enzyme supplementation, or functional additives to improve digestibility and nutrient utilization (Francis et al., 2001; Jiang et al., 2023; Hussain et al., 2024; Zaenab et al., 2026; Surianti et al., 2026).

Treatment B, containing 10% seaweed meal, produced the highest villus height but not the highest total digestibility or growth among the alternative diets. Thus, changes in intestinal morphology do not necessarily translate directly into growth when the diet contains fractions that are difficult to digest. Studies of seaweed-based diets show that growth and intestinal responses depend on seaweed species, processing method, fish species, and inclusion level; excessive inclusion can reduce palatability, feed intake, or nutrient availability (Azaza et al., 2008; Silva et al., 2015; Wan et al., 2019; Ashour et al., 2020; Siddik et al., 2023; Bakky et al., 2023; Weththasinghe et al., 2026).

Treatment A, which combined 5% seaweed meal and 5% moringa leaf meal, produced the lowest digestibility and growth. Combining two functional ingredients therefore did not produce a synergistic effect at the tested levels. The combination may have increased the cumulative fiber, ash, complex polysaccharides, and antinutritional compounds, thereby reducing palatability and nutrient availability. Sustainable aquafeed development requires nutritional compatibility and rigorous ingredient evaluation rather than relying only on the bioactive potential of individual ingredients; comparable substitution studies show that inclusion level and ingredient processing determine whether alternative materials support or suppress performance (Gatlin et al., 2007; Tacon & Metian, 2015; Hua et al., 2019; Boyd et al., 2020; Aragão et al., 2022; Herawati et al., 2026).

The blood profile supports the interpretation that treatment C was more promising than the other alternative diets. Total erythrocyte and leukocyte counts in treatment C approached those in the commercial-feed treatment and were higher than those in treatments A and B. Erythrocytes support oxygen transport, whereas leukocytes contribute to defense responses. Moringa-derived ingredients have been associated with improved hematological profiles, innate immune responses, and resistance to infection in aquatic animals (Kamble et al., 2024; Nassar et al., 2024; Saleh et al., 2025). Probiotic and symbiotic feeding studies in tilapia also confirm that dietary interventions can modify leukocyte performance, hematological indicators, immune function, and gut health (Usman et al., 2024; Rahmi et al., 2024; Rahmi et al., 2025). The response in treatment C may therefore reflect the contribution of moringa bioactive compounds to fish physiological status.

The increases in intestine somatic index and hepatosomatic index in treatments D and C indicate organ responses to nutrient status and feed metabolism. A higher hepatosomatic index in diets associated with better growth may reflect increased hepatic metabolic activity and energy storage. However, interpret a high index cautiously, as it may also reflect lipid accumulation or metabolic burden. Further research should combine organ indices with liver histology and body-composition data to distinguish healthy energy storage from metabolic stress (Villasante et al., 2025).

Water quality remained within a suitable range for saline Nile tilapia, indicating that the observed results can be interpreted mainly as dietary-treatment responses. Salinity of 13–15 ppt was within the range tolerated by Nile tilapia after gradual acclimation. Under saline conditions, high-quality feed becomes more important because fish require energy for osmoregulation in addition to growth. Alternative feed ingredients for saline tilapia should therefore be evaluated for nutrient content, digestibility, physiological effects, and their ability to support energy efficiency in a brackish environment (Thomas et al., 2021).

Overall, the results indicate that 10% moringa leaf meal is more suitable as an alternative feed ingredient for saline Nile tilapia than 10% seaweed meal or the direct combination of 5% seaweed meal and 5% moringa leaf meal. This finding shows that tropical local ingredients can support sustainable aquaculture, but formulation should be guided by an integrated evaluation of digestibility, intestinal health, blood profile, and growth. Further studies should evaluate fermentation, lower and graded inclusion levels, microbiota responses, and isoenergetic and isoproteic formulations to improve the competitiveness of local feeds in saline tilapia systems (Silva et al., 2015; Naylor et al., 2021; Jiang et al., 2023; Nassar et al., 2024; Rakhmonov et al., 2025; Zaenab et al., 2026; Rakhmonov et al., 2026).

5. CONCLUSION

Dietary inclusion of *G. verrucosa* seaweed meal and *M. oleifera* leaf meal significantly affected protein digestibility, total digestibility, and absolute weight gain of saline Nile tilapia. Commercial feed produced the highest values for these outcomes. Among the alternative diets, 10% moringa leaf meal produced the most favorable overall numerical profile, particularly for total digestibility, weight gain, villus width, and erythrocyte and leukocyte counts. The 5% seaweed meal + 5% moringa leaf meal combination showed no evidence of a synergistic response at the tested inclusion levels. Future studies should test graded inclusion levels and pretreatments such as fermentation in isoproteic and isoenergetic diets and should include microbiota assessment, liver histology, and complete inferential statistics for tissue and hematological outcomes.

Declarations

Funding: This study did not receive financial support from any organization or agency.

Acknowledgement: The authors thank the Laboratory of Aquaculture, Hatchery, and Fisheries Production, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, Indonesia; the Fish Nutrition Laboratory, Department of Aquaculture, Faculty of Fisheries and Marine Sciences, IPB University, Bogor, Indonesia; and the Center for Veterinary Assembly and Modernization, Bogor, Indonesia, for technical support during fish rearing, proximate and chromium analyses, blood profile observation, and intestinal histology examination.

Conflicts of Interest: The authors declare no financial or nonfinancial conflicts of interest that could have influenced the conduct, analysis, interpretation, or reporting of this study.

Data Availability: The main data supporting the findings of this study are presented in the article. Raw data are available from the corresponding author upon reasonable request.

Ethics Statement: The Ethical Committee for Research of the Institution of Research and Community Service, Halu Oleo University, Kendari, Indonesia approved the animal-use protocol (approval No. 1421/UN29.20.1.2/PG/2025; approved on July 7, 2025). The approval was valid for one year from the approval date. The study was conducted in accordance with applicable institutional requirements for the use of animal subjects.

Author's Contributions: WHM: conceptualization, methodology, project administration, supervision, and writing - review and editing. ZB: investigation, data collection, data curation, formal analysis, and writing - original draft. R: methodology, validation, resources, and writing - review and editing. IN: methodology, data interpretation, validation, and writing - review and editing. AK: supervision, methodology, validation, and writing - review and editing. MH: investigation, resources, validation, and writing - review and editing. LOBA: investigation, data curation, visualization, and writing - review and editing. H: methodology, validation, and writing - review and editing. LOMM: formal analysis, validation, data interpretation, and writing - review and editing. All authors read and approved the final manuscript.

Generative AI Statements: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

Publisher's Note: All claims stated in this article are exclusively those of the authors and do not necessarily represent those of their affiliated organizations or those of the publisher, the editors, and the reviewers. Any product that may be evaluated/assessed in this article or claimed by its manufacturer is not guaranteed or endorsed by the publisher/editors.

REFERENCES

- Aanyu, M., Ondhoro, C. C., Ganda, E., Kato, D. C., & Basiita, R. K. (2014). Intestine histology, nutrient digestibility and body composition of Nile tilapia (*Oreochromis niloticus*) fed on diets with both cotton and sunflower seed cakes. *African Journal of Biotechnology*, 13(37), 3831–3839. <https://doi.org/10.5897/AJB12.1895>
- Afuang, W., Siddhuraju, P., & Becker, K. (2003). Comparative nutritional evaluation of raw, methanol extracted residues and methanol extracts of moringa (*Moringa oleifera* Lam.) leaves on growth performance and feed utilization in Nile tilapia (*Oreochromis niloticus* L.). *Aquaculture Research*, 34(13), 1147–1159. <https://doi.org/10.1046/j.1365-2109.2003.00920.x>
- Aragão, C., Gonçalves, A. T., Costas, B., Azeredo, R., Xavier, M. J., & Engrola, S. (2022). Alternative proteins for fish diets: Implications beyond growth. *Animals*, 12(9), 1211. <https://doi.org/10.3390/ani12091211>
- Ashour, M., Mabrouk, M. M., Ayoub, H. F., El-Feky, M. M. M. M., Zaki, S. Z., Hoseinifar, S. H., Rossi, W., Van Doan, H., El-Haroun, E., & Goda, A. M. A.-S. (2020). Effect of dietary seaweed extract supplementation on growth, feed utilization, hematological indices, and non-specific immunity of Nile tilapia, *Oreochromis niloticus* challenged with *Aeromonas hydrophila*. *Journal of Applied Phycology*, 32(5), 3467–3479. <https://doi.org/10.1007/s10811-020-02178-1>
- Azaza, M. S., Mensi, F., Ksouri, J., Dhraief, M. N., Brini, B., Abdelmouleh, A., & Kraïem, M. M. (2008). Growth of Nile tilapia (*Oreochromis niloticus* L.) fed with diets containing graded levels of green algae ulva meal (*Ulva rigida*) reared in geothermal waters of southern Tunisia. *Journal of Applied Ichthyology*, 24(2), 202–207. <https://doi.org/10.1111/j.1439-0426.2007.01017.x>
- Bakky, M. A. H., Tran, N. T., Zhang, Y., Hu, H., Lin, H., Zhang, M., Liang, H., Zhang, Y., & Li, S. (2023). Effects of dietary supplementation of *Gracilaria lemaneiformis*-derived sulfated polysaccharides on the growth, antioxidant capacity, and innate

Citation: Muskita, W.H., Bahtiar, Z., Ruslaini, Nur, I., Kurnia, A., Hamzah, M., Abidin, L.O.B., Hamsah, & Munadi, L.O.M. (2026). Combination of seaweed meal (*Gracilaria verrucosa*) and moringa leaf meal (*Moringa oleifera*) in diets on digestibility, intestinal histology, blood profile, and growth of Nile tilapia (*Oreochromis niloticus*). *Agrobiological Records*, 26, 59-68. <https://doi.org/10.47278/journal.abr/2026.083>

- immunity of rabbitfish (*Siganus canaliculatus*). *Fish & Shellfish Immunology*, 139, 108933. <https://doi.org/10.1016/j.fsi.2023.108933>
- Boyd, C. E., D'Abramo, L. R., Glencross, B. D., Huyben, D. C., Juarez, L. M., Lockwood, G. S., McNevin, A. A., Tacon, A. G. J., Teletchea, F., Tomasso, J. R., Tucker, C. S., & Valenti, W. C. (2020). Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. *Journal of the World Aquaculture Society*, 51(3), 578–633. <https://doi.org/10.1111/jwas.12714>
- Food and Agriculture Organization of the United Nations (FAO) (2024). The state of world fisheries and aquaculture 2024: Blue transformation in action. <https://doi.org/10.4060/cd0683en>
- Francis, G., Makkar, H. P. S., & Becker, K. (2001). Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. *Aquaculture*, 199(3–4), 197–227. [https://doi.org/10.1016/S0044-8486\(01\)00526-9](https://doi.org/10.1016/S0044-8486(01)00526-9)
- Gatlin, D. M., Barrows, F. T., Brown, P., Dabrowski, K., Gaylord, T. G., Hardy, R. W., Herman, E., Hu, G., Krogdahl, Å., Nelson, R., Overturf, K., Rust, M., Sealey, W., Skonberg, D., Souza, E. J., Stone, D., Wilson, R., & Wurtele, E. (2007). Expanding the utilization of sustainable plant products in aquafeeds: A review. *Aquaculture Research*, 38(6), 551–579. <https://doi.org/10.1111/j.1365-2109.2007.01704.x>
- Glencross, B. D. (2020). A feed is still only as good as its ingredients: An update on the nutritional research strategies for the optimal evaluation of ingredients for aquaculture feeds. *Aquaculture Nutrition*, 26(6), 1871–1883. <https://doi.org/10.1111/anu.13138>
- Herawati, V. E., Windarto, S., Indriati, D. A., Arfan, M., Anggraeni, N., & Rismaningsih, N. (2026). Substitution of fish meal with mealworm (*Tenebrio molitor*) meal for nutritional quality, feed utilization efficiency and growth performance of Nile tilapia (*Oreochromis niloticus*). *International Journal of Agriculture and Biosciences*, 15(2), 745–753. <https://doi.org/10.47278/journal.ijab/2025.221>
- Hua, K., Cobcroft, J. M., Cole, A., Condon, K., Jerry, D. R., Mangott, A., Praeger, C., Vucko, M. J., Zeng, C., Zenger, K., & Strugnelli, J. M. (2019). The future of aquatic protein: Implications for protein sources in aquaculture diets. *One Earth*, 1(3), 316–329. <https://doi.org/10.1016/j.oneear.2019.10.018>
- Hussain, S. M., Bano, A. A., Ali, S., Rizwan, M., Adrees, M., Zahoor, A. F., Sarker, P. K., Hussain, M., Arsalan, M. Z.-H., Yong, J. W. H., & Naem, A. (2024). Substitution of fishmeal: Highlights of potential plant protein sources for aquaculture sustainability. *Heliyon*, 10(4), e26573. <https://doi.org/10.1016/j.heliyon.2024.e26573>
- Ikeogu, C. F., Okpala-Ezennia, K. P., & Egwudike, A. C. (2022). Growth performance of African catfish (*Clarias gariepinus*) juveniles cultured with fish feeds formulated with different nutritional components. *Agrobiological Records*, 9, 1–6. <https://doi.org/10.47278/journal.abr/2022.008>
- Jiang, W., Qian, L., Zhao, Y., Lin, Y., Yang, Y., Shen, H., Ge, X., & Miao, L. (2023). The application of *Moringa oleifera* leaf meal and its fermentation products in the diet of *Megalobrama amblycephala* juveniles. *Fermentation*, 9(6), 577. <https://doi.org/10.3390/fermentation9060577>
- Kamble, M. T., Gallardo, W., Salin, K. R., Pumpuang, S., Chavan, B. R., Bhujel, R. C., Medhe, S. V., Kettawan, A., Thompson, K. D., & Pirarat, N. (2024). Effect of *Moringa oleifera* leaf extract on the growth performance, hematology, innate immunity, and disease resistance of Nile tilapia (*Oreochromis niloticus*) against *Streptococcus agalactiae* biotype 2. *Animals*, 14(6), 953. <https://doi.org/10.3390/ani14060953>
- Köprücü, K. & Özdemir, Y. (2005). Apparent digestibility of selected feed ingredients for Nile tilapia (*Oreochromis niloticus*). *Aquaculture*, 250(1–2), 308–316. <https://doi.org/10.1016/j.aquaculture.2004.12.003>
- Masriah, A., Zaenab, S., Khatimah, K., & Sompia, A. (2026). Growth performance of Nile tilapia (*Oreochromis niloticus*) fed liquid bioslurry-supplemented feed in floating net cages. *International Journal of Veterinary Science*, 15(1), 297–303. <https://doi.org/10.47278/journal.ijvs/2025.138>
- Mmanda, F. P., Lindberg, J. E., Norman Haldén, A., Mtolera, M. S. P., Kitula, R., & Lundh, T. (2020). Digestibility of local feed ingredients in tilapia *Oreochromis niloticus* juveniles, determined on faeces collected by siphoning or stripping. *Fishes*, 5(4), 32. <https://doi.org/10.3390/fishes5040032>
- Nassar, A. A. M. A., Gharib, A. A. E.-A., Abdelgalil, S. Y., AbdAllah, H. M., & Elmowalid, G. A. (2024). Immunomodulatory, antioxidant, and growth-promoting activities of dietary fermented *Moringa oleifera* in Nile tilapia (*Oreochromis niloticus*) with in-vivo protection against *Aeromonas hydrophila*. *BMC Veterinary Research*, 20(1), 231. <https://doi.org/10.1186/s12917-024-04070-3>
- Naylor, R. L., Hardy, R. W., Buschmann, A. H., Bush, S. R., Cao, L., Klinger, D. H., Little, D. C., Lubchenco, J., Shumway, S. E., & Troell, M. (2021). A 20-year retrospective review of global aquaculture. *Nature*, 591(7851), 551–563. <https://doi.org/10.1038/s41586-021-03308-6>
- Rahmi, Relatami, A. N. R., Anshar, A. R., Akmal, Syaichudin, M., Firman, S. W., Tampangallo, B. R., Mundayana, Y., Chadijah, A., Nisaa, K., Salam, N. I., Masriah, A., Ikbali, M., Indahyani, F., Hoven, I. D., & Muzalina, E. (2024). Growth analysis and innate immune response of tilapia (*Oreochromis niloticus*) fed with synbiotic feeds in brackish water. *International Journal of Veterinary Science*, 13(3), 291–299. <https://doi.org/10.47278/journal.ijvs/2023.100>
- Rahmi, Salam, N. I., Relatami, A. N. R., Anshar, A. R., Akmal, Syaichudin, M., Suwoyo, H. S., Mundayana, Y., Nisaa, K., Yani, F. I., & Muzalina, E. (2025). Effects of synbiotic supplementation on growth performance, hematological parameters and gut health in Nile tilapia (*Oreochromis niloticus*). *International Journal of Veterinary Science*, 14(3), 470–477. <https://doi.org/10.47278/journal.ijvs/2024.273>
- Rakhmonov, V., Turdalieva, K., Bobokandov, N., Isomov, E., Tashmanov, R., Pulatov, I., Kobulova, B., Dustov, B., Shernazarov, S., Nurimov, P., Mamadiyarova, D., Kuvvatov, K., & Tashpulatov, Y. (2025). Intensive cultivation of vascular aquatic plants in

Citation: Muskita, W.H., Bahtiar, Z., Ruslaini, Nur, I., Kurnia, A., Hamzah, M., Abidin, L.O.B., Hamsah, & Munadi, L.O.M. (2026). Combination of seaweed meal (*Gracilaria verrucosa*) and moringa leaf meal (*Moringa oleifera*) in diets on digestibility, intestinal histology, blood profile, and growth of Nile tilapia (*Oreochromis niloticus*). *Agrobiological Records*, 26, 59-68. <https://doi.org/10.47278/journal.abr/2026.083>

- the conditions of the central regions of Uzbekistan and preparation of feed for herbivorous fish. *International Journal of Agriculture and Biosciences*, 14(6), 1088–1097. <https://doi.org/10.47278/journal.ijab/2025.131>
- Rakhmonov, V., Shernazarov, S., Rakhmonova, K., Pulatov, I., Nurmurzaev, Z., Nurniyozov, A., Mukhammadova, S., Niyozov, K., Atafulova, M., Aytbayeva, K., Kaipov, K., Bobokandov, N., & Tashpulatov, Y. (2026). Evaluation of *Azolla caroliniana* and *Lemna* minor biomass effects on fish growth performance and feed efficiency under sustainable aquaculture conditions. *Agrobiological Records*, 24, 95–110. <https://doi.org/10.47278/journal.abr/2026.028>
- Ramos, M. A., Batista, S., Pires, M. A., Silva, A. P., Pereira, L. F., Saavedra, M. J., Ozório, R. O. A., & Rema, P. (2017). Dietary probiotic supplementation improves growth and the intestinal morphology of Nile tilapia. *Animal*, 11(8), 1259–1269. <https://doi.org/10.1017/S1751731116002792>
- Richter, N., Siddhuraju, P., & Becker, K. (2003). Evaluation of nutritional quality of moringa (*Moringa oleifera* Lam.) leaves as an alternative protein source for Nile tilapia (*Oreochromis niloticus* L.). *Aquaculture*, 217(1–4), 599–611. [https://doi.org/10.1016/S0044-8486\(02\)00497-0](https://doi.org/10.1016/S0044-8486(02)00497-0)
- Saini, R. K., Sivanesan, I., & Keum, Y.-S. (2016). Phytochemicals of *Moringa oleifera*: A review of their nutritional, therapeutic, and industrial significance. *3 Biotech*, 6(2), 203. <https://doi.org/10.1007/s13205-016-0526-3>
- Saleh, S. Y., Younis, N. A., Sherif, A. H., & Gaber, H. G. (2025). The role of *Moringa oleifera* in enhancing fish performance and health: A comprehensive review of sustainable aquaculture applications. *Veterinary Research Communications*, 49(6), 308. <https://doi.org/10.1007/s11259-025-10889-4>
- Siddik, M. A. B., Francis, P., Rohani, M. F., Azam, M. S., Mock, T. S., & Francis, D. S. (2023). Seaweed and seaweed-based functional metabolites as potential modulators of growth, immune and antioxidant responses, and gut microbiota in fish. *Antioxidants*, 12(12), 2066. <https://doi.org/10.3390/antiox12122066>
- Silva, D. M., Valente, L. M. P., Sousa-Pinto, I., Pereira, R., Pires, M. A., Seixas, F., & Rema, P. (2015). Evaluation of IMTA-produced seaweeds (*Gracilaria*, *Porphyra*, and *Ulva*) as dietary ingredients in Nile tilapia, *Oreochromis niloticus* L., juveniles. Effects on growth performance and gut histology. *Journal of Applied Phycology*, 27(4), 1671–1680. <https://doi.org/10.1007/s10811-014-0453-9>
- Surianti, Zainuddin, Aslamyah, S., & Azis, H. Y. (2026). Microbial fermented duck bone meal enhances digestibility and feed efficiency in *Litopenaeus vannamei* toward sustainable aquafeed. *International Journal of Agriculture and Biosciences*, 15(3), 1235–1241. <https://doi.org/10.47278/journal.ijab/2026.035>
- Tacon, A. G. J., & Metian, M. (2015). Feed matters: Satisfying the feed demand of aquaculture. *Reviews in Fisheries Science & Aquaculture*, 23(1), 1–10. <https://doi.org/10.1080/23308249.2014.987209>
- Thomas, R. M., Verma, A. K., Krishna, H., Prakash, S., Kumar, A., & Peter, R. M. (2021). Effect of salinity on growth of Nile tilapia (*Oreochromis niloticus*) and spinach (*Spinacia oleracea*) in aquaponic system using inland saline groundwater. *Aquaculture Research*, 52(12), 6288–6298. <https://doi.org/10.1111/are.15492>
- Usman, U., Khaliq, A., Akram, F., Afzal, H., & Aziz, S. (2024). A review on the role of *Bacillus* spp. as probiotics in tilapia culture. *Agrobiological Records*, 18, 80–95. <https://doi.org/10.47278/journal.abr/2024.040>
- Villasante, A., Figueroa, E., Godoy, K., Dantagnan, P., López-Polo, J., Opazo, R., & Romero, J. (2025). Impact of plant-based diets on hepatosomatic index, circulating globulins, and growth in rainbow trout (*Oncorhynchus mykiss*). *Fishes*, 10(3), 110. <https://doi.org/10.3390/fishes10030110>
- Wan, A. H. L., Davies, S. J., Soler-Vila, A., Fitzgerald, R., & Johnson, M. P. (2019). Macroalgae as a sustainable aquafeed ingredient. *Reviews in Aquaculture*, 11(3), 458–492. <https://doi.org/10.1111/raq.12241>
- Weththasinghe, P., Thilakarathne, H. M. T. P., Herath, H. M. U. L., & Jayawardana, B. C. (2026). Meta-analysis of the effects of seaweed inclusion in fish diets on growth performance. *Aquaculture*, 611, 743085. <https://doi.org/10.1016/j.aquaculture.2025.743085>
- Zaenab, S., Zainuddin, Sriwulan, & Nisaa, K. (2026). Evaluation of growth performance of bioslurry isolated bacteria and their application in *Ceratophyllum* sp. fermentation for sustainable fish feed. *International Journal of Agriculture and Biosciences*, 15(1), 283–289. <https://doi.org/10.47278/journal.ijab/2025.178>

Citation: Muskita, W.H., Bahtiar, Z., Ruslaini, Nur, I., Kurnia, A., Hamzah, M., Abidin, L.O.B., Hamsah, & Munadi, L.O.M. (2026). Combination of seaweed meal (*Gracilaria verrucosa*) and moringa leaf meal (*Moringa oleifera*) in diets on digestibility, intestinal histology, blood profile, and growth of Nile tilapia (*Oreochromis niloticus*). *Agrobiological Records*, 26, 59-68. <https://doi.org/10.47278/journal.abr/2026.083>