

Effects of Dietary Cucumber Tree Leaf Extract (*Averrhoa bilimbi*) Supplementation on Survival and Growth Performance of Bilih Fish (*Rasbora maninjau*)

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ABSTRACT

This study investigated the effect of dietary supplementation with cucumber tree leaf extract (*Averrhoa bilimbi*) as a natural feed additive on the survival and growth performance of bilih fish (*Rasbora maninjau*). Leaves of *A. bilimbi* were dried, ground, and macerated in 96% ethanol (1:10 w/v) for 72 h. The solvent was evaporated, and the viscous extract was stored at 4°C prior to feed incorporation. A completely randomized design (CRD) was applied, comprising four dietary treatments with three replicates each: P0 (control, no extract), P1 (1% extract), P2 (3% extract), and P3 (5% extract) per kilogram of feed. Juvenile bilih fish measuring 2–3 cm in length were stocked at a density of one fish per liter and reared for 40 days. Feed was administered at 3% of biomass daily in two equal meals. Key response variables included survival rate and growth performance. Analysis of variance (ANOVA) revealed that dietary supplementation with cucumber tree leaf extract had a significant effect on growth performance ($p < 0.05$) but exerted no significant influence on survival rate ($p \geq 0.05$). The optimal supplementation dose was approximately 3% (P2), with lower or higher doses resulting in reduced growth performance. *A. bilimbi* may be effective as a natural feed supplement for improving the growth of *R. maninjau*, possibly because of its bioactive compound content and the slight increase in the dietary protein level.

Keywords: Dietary supplement, Fry nursing, Growth performance, Phytochemical

INTRODUCTION

Bilih fish (*Rasbora maninjau*) is one of the four newly identified *Rasbora* species belonging to the Sumatran group, and has been reported from several regions of Sumatra, including riverine and swamp habitats in Aceh (Lumbantobing, 2014). The aquaculture of bilih fish is currently being developed by local farmers in Aceh, especially in the Nagan Raya and West Aceh regions. Bilih fish has high economic value and serves as one of the main sources of income for local communities. Fluctuations in the price of *R. maninjau* are generally influenced by natural conditions and consumer

demand (Zulfadhli *et al.*, 2023). Although bilih fish farming has been practiced by local farmers in Nagan Raya, its cultivation still faces challenges, particularly a relatively slow growth rate compared with other fish species.

In small-scale aquaculture, suboptimal feed quality and limited access to cost-effective feed additives may contribute to poor growth performance and reduced production efficiency. To address these limitations, innovations in natural dietary supplementation are necessary, particularly through the use of low-cost medicinal plants from the local flora of Aceh to improve feed utilization,

growth performance, and health in *R. maninjau*. This approach aims to provide a sustainable solution that supports the growth and health of the fish while reducing feed costs and environmental impacts. Several studies support the use of medicinal plants as phyto-genic feed additives in aquaculture (Awad and Awaad, 2017; Kuebutornye and Abarike, 2020; Tadese *et al.*, 2022). The development of local feed innovations also has the potential to reduce reliance on commercial feed while simultaneously supporting economic and environmental sustainability in aquaculture (Mansour, 2025; Nathanailides, 2025).

Averrhoa bilimbi is an abundant local plant with considerable potential as a natural dietary supplement in fish feed. This plant contains various bioactive compounds that may support fish growth, immunity, and physiological resilience, including formic acid, citric acid, vitamin C, saponins, tannins, glycosides, flavonoids, and minerals such as potassium citrate and potassium oxalate (Alhassan and Ahmed, 2016; Maulianawati *et al.*, 2025). In addition to vitamins, *A. bilimbi* is also rich in important minerals such as calcium, magnesium, potassium, and phosphorus, making it potentially useful as a natural feed supplement to enhance the nutritional value and resilience of fish in aquaculture (Ferreira *et al.*, 2021; Iwansyah *et al.*, 2021). The use of *A. bilimbi* provides notable benefits, including its potential as a natural and environmentally friendly additive relative to synthetic growth promoters or antibiotics (Rarassari *et al.*, 2025), as well as its ease of application by local communities in extract form (Zakaria *et al.*, 2007).

However, research on *A. bilimbi* supplementation in aquafeed formulations remains relatively uncommon. To date, several other local plants have been utilized as dietary additives to stimulate the growth of *R. maninjau*, such as water hyacinth meal (Islama *et al.*, 2023), taro leaf meal (Zahtul *et al.*, 2023) and moringa leaf meal (Puycha *et al.*, 2017). Several studies have reported positive outcomes from the use of *A. bilimbi* leaf extract in fish feed, including enhanced growth performance in common carp (*Cyprinus carpio*) (Nguyen

et al., 2022) and Nile tilapia (*Oreochromis niloticus*) (Kumar *et al.*, 2018; Rarassari *et al.*, 2025). Given its abundance in Aceh, further exploration of this plant's potential is warranted. Therefore, the present study aimed to evaluate the effects of incorporating *A. bilimbi* leaf extract into feed formulations on the survival and growth performance of *R. maninjau*.

MATERIALS AND METHODS

Research site and duration

The experiment was conducted from August to September 2024 at the Hatchery and Aquaculture Systems and Environment Laboratory, Faculty of Fisheries and Marine Sciences, Teuku Umar University, Meulaboh, West Aceh, Aceh, Indonesia. Proximate analyses of the experimental diets were carried out at the Industrial Standardization and Service Center (Balai Standardisasi dan Pelayanan Jasa Industri), Banda Aceh, Aceh, Indonesia.

Experimental design

This study employed a completely randomized design (CRD) with four dietary treatments and three replicates per treatment. The factor tested was dietary supplementation with *A. bilimbi* leaf extract at different inclusion levels (0, 1%, 3%, and 5% w/w) in a locally sourced basal diet.

Research procedure

Preparation of experimental diets

The feed formulations were designed to meet the optimal protein requirements of *R. maninjau* during the grow-out phase. The experimental diets were formulated to contain a minimum of 30% crude protein, which is considered appropriate for species belonging to the Cyprinidae family. The feed formulations were calculated using the Smartfish application to ensure a balanced and accurate nutrient composition (Table 1).

Table 1. Composition of the experimental diets supplemented with different levels of *Averrhoa bilimbi* leaf extract.

Raw materials	Composition (%)				Total (g)	REQ. (g)
	P0	P1	P2	P3		
Fish meal	400.00	400.00	400.00	400.00	1,600	2,400
Fermented moringa leaf flour	200.00	200.00	200.00	200.00	800	1,200
Soybean flour	124.00	124.00	124.00	124.00	496	744
Polishing	181.70	171.70	151.70	131.70	637	955
Corn flour	50.00	50.00	50.00	50.00	200	300
Fish oil	5.00	5.00	5.00	5.00	20	30
Palm oil	5.00	5.00	5.00	5.00	20	30
L-Lysine	16.00	16.00	16.00	16.00	64	96
L-Methionine	10.00	10.00	10.00	10.00	40	60
Cucumber tree leaf extract	-	10.00	30.00	50.00	90	135
Phytase enzyme	0.28	0.28	0.28	0.28	1	2
Premiks	5.00	5.00	5.00	5.00	20	30
CMC	300	3.00	3.00	3.00	12	18
Total	1,000	1,000	1,000	1,000	4,000	6,000

The feed ingredients were first weighed according to the formulation and then finely ground to achieve a uniform particle size. All dry ingredients were thoroughly mixed using a feed mixer until homogeneous. *A. bilimbi* leaf extract was added to the diets according to the treatment levels, followed by the addition of warm water (approximately 30–40 °C) to aid in dough formation. To achieve homogeneity, the ingredients were mixed gradually, beginning with the those present in the smallest amounts and proceeding to those present in larger amounts. The resulting dough was shaped into pellets using a fish-feed pelleting machine.

Preparation of Averrhoa bilimbi leaf extract

Fresh *A. bilimbi* leaves were collected from Meulaboh, West Aceh, Aceh, Indonesia, washed with clean water, sun-dried, and ground into fine powder. The extraction procedure was adapted, with minor modifications, from previous solvent maceration methods for *A. bilimbi* extracts (Putri *et al.*, 2023; Anindya *et al.*, 2024). The dried leaf powder was macerated with 96% ethanol at

a ratio of 1:10 w/v for 72 h at room temperature (20–25 °C) under dark conditions. The mixture was filtered using Whatman No. 1 filter paper, and the residue was re-extracted once under the same conditions. The combined filtrates were concentrated using a rotary evaporator at 40 °C and further dried in a vacuum oven at ≤40 °C until constant weight and no ethanol odor remained. The extraction yield was calculated as (dry extract weight/dry powder weight) × 100, and the viscous extract was stored in amber bottles at 4 °C until use.

The extract was incorporated into the basal diet at 1%, 3%, and 5%, equivalent to 10, 30, and 50 g·kg⁻¹ feed, respectively. Before mixing, the extract was diluted with a small amount of vegetable oil to obtain a sprayable suspension, and the same amount of oil was added to all diets, including the control. The suspension was gradually sprayed onto the feed ingredients while mixing for 5–10 min to ensure uniform distribution. The diets were pelleted into pellets measuring 0.8–1.2 mm, oven-dried at 40 °C until the target moisture level was reached, packed in airtight containers, and stored at 4 °C until feeding.

Preparation of rearing tanks and experimental fish

A total of 12 aquaria (40×30×30 cm) were used in this study. Prior to the experiment, all aquaria were thoroughly cleaned, equipped with aeration systems, and filled with water to a depth of 25 cm. The aquaria were then arranged according to the experimental design. Each aquarium was stocked with 30 bilih fish (*R. maninjau*), measuring 2–3 cm in total length, corresponding to a stocking density of approximately 1 fish·L⁻¹. The experimental fish were obtained from the hatchery of Teuku Umar University.

Fish rearing

The experimental fish were reared for 40 days following a 7-day acclimatization period. Fish were randomly distributed among the tanks and maintained at ambient temperature. Initial weight and length measurements were taken at the beginning of the experiment using a digital balance with a readability of 0.01 g and vernier calipers. Fish were fed a daily ration equivalent to 3% of their body biomass, administered twice daily in the morning and evening.

Collection of data

Because the experimental fish were very small (2–3 cm in initial total length), body weight was measured as pooled biomass per replicate rather than individually to avoid excessive handling stress. At each sampling interval, 30% of the fish from each replicate were randomly collected. Their total length was measured in centimeters using vernier calipers, and their pooled body weight was recorded in grams using a digital balance with a readability of 0.01 g. Water quality parameters were monitored weekly, including pH using a portable pH meter (pH Testr30; Eutech, Singapore) and dissolved oxygen (DO), and temperature using an oxygen probe (Pro20i; YSI, USA). At the conclusion of the experiment, the number of surviving fish in each treatment was counted, and the final total length of each sampled fish and the pooled body weight per replicate were recorded. The parameters

assessed to evaluate the growth and survival of the fish included survival rate (SR), absolute weight gain (AWG), absolute length gain (ALG), specific growth rate (SGR), daily growth rate (DGR), and feed efficiency (FE), based on standard formulae widely used in aquaculture research (Muchlisin *et al.*, 2016; Islama *et al.*, 2025).

Survival rate was calculated as the percentage of fish remaining alive at the end of the experimental period relative to the initial number of stocked fish:

$$SR = (N_t/N_0) \times 100$$

where SR is the survival rate (%), N_t is the number of fish at the end of the experiment, and N_0 is the number of fish stocked at the beginning of the experiment.

Absolute length gain and absolute weight gain were determined as the differences between the final and initial mean length and weight, respectively, of fish during the rearing period:

$$ALG = L_t - L_0$$

where ALG is the absolute length gain (cm), L_t is the final fish length (cm), and L_0 is the initial fish length (cm).

$$AWG = W_t - W_0$$

where AWG is the absolute weight gain (g), W_t is the final fish weight (g), and W_0 is the initial fish weight (g).

Specific growth rate was calculated using the natural logarithmic difference between the final and initial mean fish weight, as commonly applied in aquaculture growth studies (Lugert *et al.*, 2016:

$$SGR = [\ln(W_t) - \ln(W_0)]/t \times 100$$

where SGR is the specific growth rate (%·day⁻¹), W_t is the final mean fish weight (g), W_0 is the initial mean fish weight (g), and t is the duration of the experimental period (days).

Daily growth rate was calculated as the average daily increase in fish body weight during the rearing period:

$$\text{DGR} = (\text{Wt} - \text{Wo}) / t$$

where DGR is the daily growth rate ($\text{g} \cdot \text{day}^{-1}$), Wt is the final mean fish weight (g), Wo is the initial mean fish weight (g), and t is the duration of the experimental period (days).

Feed efficiency was calculated according to Mumpuni *et al.* (2022):

$$\text{FE} = [(\text{Wt} + \text{D}) - \text{Wo}] / \text{F} \times 100$$

where FE is feed efficiency (%), Wt is the final fish biomass (g), Wo is the initial fish biomass (g), D is the biomass of fish that died during the experiment (g), and F is the total feed intake (g).

Data analysis

Data were processed using Microsoft Excel with appropriate formulas. Statistical analyses were performed using SPSS version 27. Treatment effects were analyzed using one-way analysis of variance (ANOVA). When significant differences were detected, Duncan's multiple range test was applied at a significance level of $p < 0.05$. Data are presented as the mean $\pm$ standard deviation (Field, 2018).

RESULTS

Analysis of variance (ANOVA) showed that supplementation with *A. bilimbi* leaf extract had a significant effect on the growth parameters of *R. maninjau* ($p < 0.05$), but had no significant effect on survival rate ($p \geq 0.05$). Treatment P2 (3% extract per kg feed) produced significantly higher absolute weight gain (AWG), absolute length gain (ALG), specific growth rate (SGR), daily growth rate (DGR), and feed efficiency (FE) than the control (P0) and the other treatments (P1 and P3), as shown in Table 2.

Proximate analysis of the feed showed minor variations in nutrient composition, particularly protein and carbohydrate content. However, the crude protein content of all diets remained above 30%, consistent with the nutritional requirements of cyprinid fish (Table 3). Treatment P2 had the highest crude protein content, but the differences among treatments were small. Therefore, the improved growth performance of *R. maninjau* may have resulted from the combined effects of the bioactive compounds in *A. bilimbi* leaf extract (Table 4) and the slight differences in the nutritional composition of the experimental diets.

Water quality parameters recorded during the 40-day rearing period, including temperature, pH, and dissolved oxygen (DO), remained relatively stable across all dietary treatments (Table 5).

Table 2. Survival and growth performance of *Rasbora maninjau* fed locally formulated diets supplemented with varying levels of *Averrhoa bilimbi* leaf extract.

Treatment	Parameters							
	Wo (g)	Wt (g)	SR (%)	AWG (g)	ALG (cm)	SGR ($\% \cdot \text{day}^{-1}$)	DGR ($\text{g} \cdot \text{day}^{-1}$)	FE (%)
P0	0.25 $\pm$ 0.0 ^a	0.38 $\pm$ 0.02 ^a	98.67 $\pm$ 2.31 ^a	0.13 $\pm$ 0.02 ^a	1.05 $\pm$ 0.10 ^a	1.04 $\pm$ 0.13 ^a	0.003 $\pm$ 0.00 ^a	20.15 $\pm$ 1.42 ^a
P1	0.25 $\pm$ 0.0 ^a	0.47 $\pm$ 0.02 ^b	98.67 $\pm$ 2.31 ^a	0.22 $\pm$ 0.02 ^b	1.28 $\pm$ 0.07 ^b	1.59 $\pm$ 0.13 ^{bc}	0.006 $\pm$ 0.00 ^b	25.27 $\pm$ 2.05 ^b
P2	0.25 $\pm$ 0.0 ^a	0.52 $\pm$ 0.03 ^c	98.67 $\pm$ 2.31 ^a	0.27 $\pm$ 0.03 ^c	1.50 $\pm$ 0.08 ^c	1.81 $\pm$ 0.22 ^c	0.007 $\pm$ 0.00 ^b	28.03 $\pm$ 2.04 ^b
P3	0.25 $\pm$ 0.0 ^a	0.43 $\pm$ 0.03 ^{bc}	100.00 $\pm$ 0.00 ^a	0.18 $\pm$ 0.04 ^b	1.25 $\pm$ 0.12 ^b	1.34 $\pm$ 0.15 ^b	0.005 $\pm$ 0.00 ^b	23.79 $\pm$ 1.47 ^{ab}

Note: Mean $\pm$ SD within the same column followed by different lowercase superscript letters are significantly different ($p < 0.05$); P0 = Control (0% extract); P1 = 1% extract; P2 = 3% extract; P3 = 5% extract.

Table 3. Proximate composition of the experimental diets supplemented with different levels of *Averrhoa bilimbi* leaf extract.

Treatment	Water content (%)	Crude ash (%)	Fat (%)	Protein (%)	Crude fiber (%)	Carbohydrate (%)
P0	8.22	6.55	5.69	31.47	2.85	45.32
P1	7.05	6.82	5.75	32.94	2.24	45.20
P2	7.74	6.12	5.83	33.05	2.47	44.79
P3	7.38	6.33	5.91	32.99	2.56	44.83

Note: P0 = Control (0% extract); P1 = 1% extract; P2 = 3% extract; P3 = 5% extract.

Table 4. Preliminary phytochemical profile of *Averrhoa bilimbi* leaf extract compared with previously reported findings.

Metabolite content	Reagent	Current result	Comparison of results	
			Maulianawati <i>et al.</i> (2025)	Valsan <i>et al.</i> (2016)
Alkaloids	Dragendorff	+	+	+
Flavonoids	HCL dan Logam Mg	+	+	+
Terpenoids	Liebermann-Burchard test	+	+	+
Tannis	FeCL ₃	+	+	+
Saponins	H ₂ Oshake	+	+	-
Steroids	Liebermann-Burchard test	+	+	+

Table 5. Water quality parameters recorded during the 40-day rearing period of *Rasbora maninjau* under different dietary treatments.

Parameter	Treatment			
	P0	P1	P2	P3
Temperature (°C)	25.6–26.4	25.5–26.1	25.8–26.2	25.4–26.5
pH	7.61–8.49	7.59–8.31	7.58–8.30	7.55–8.21
DO (mg·L ⁻¹)	6.25–6.74	6.44–7.28	6.37–7.15	6.35–7.22

Note: P0 = Control (0% extract); P1 = 1% extract; P2 = 3% extract; P3 = 5% extract

Temperature ranged from 25.4 to 26.5 °C, pH ranged from 7.55 to 8.49, and DO ranged from 6.25 to 7.28 mg·L⁻¹ throughout the experimental period.

DISCUSSION

Survival performance

The survival rate of *R. maninjau* consistently exceeded 90%, indicating acceptable survival under aquaculture conditions. The high survival across all treatments suggests that the experimental conditions were suitable and that dietary supplementation with

A. bilimbi extract at the tested inclusion levels caused no apparent adverse effects.

Fish survival is not only by feed but also by extrinsic factors, including water quality, handling, and stress, as well as intrinsic physiological conditions (Petitjean *et al.*, 2019; Mansou *et al.*, 2023; Mariu *et al.*, 2023). Therefore, the consistently high survival rate may have been partly associated with suitable water quality maintained during the rearing period. However, because survival did not differ significantly among treatments, the results do not demonstrate a direct survival-enhancing effect of *A. bilimbi*.

The absence of significant differences in survival is consistent with previous studies reporting that plant-based feed additives may improve physiological condition or growth without measurably increasing survival under non-challenging culture conditions. In rohu (*Labeo rohita*), *A. bilimbi* extract improved hematological and immune parameters that could potentially reduce disease-related mortality (Debnath *et al.*, 2025). However, because these parameters were not evaluated in the present study, this proposed mechanism remains hypothetical rather than directly supported by the current findings.

Studies on Nile tilapia (Hossain *et al.*, 2018; Kumar *et al.*, 2018), common carp (Sivakumar *et al.*, 2015), and African catfish (*Clarias gariepinus*) (Adebayo *et al.*, 2019) similarly reported no significant differences in survival between control and *A. bilimbi*-supplemented groups. Under favorable culture conditions, the effects of dietary additives on survival may be difficult to detect because survival is strongly influenced by environmental quality, husbandry practices, stocking density, and handling stress (Nathanailides, 2025).

Effects of Averrhoa bilimbi on growth performance

The use of *A. bilimbi* as a natural dietary supplement may provide an environmentally friendly strategy for improving feed performance. In the present study, supplementation with *A. bilimbi* improved the growth performance of *R. maninjau*, particularly at the 3% inclusion level. Fish in the supplemented groups, especially those in P2 showed higher final weight, absolute weight gain, absolute length gain, specific growth rate, daily growth rate, and feed efficiency than fish in the control group.

Potential growth-promoting mechanisms

The growth-promoting effects of *A. bilimbi* may be associated with its bioactive and nutritional compounds, including flavonoids, alkaloids, and saponins identified in the present study (Table 4). These compounds may function as natural antioxidants and growth-promoting phytobiotics. *A. bilimbi* also contains vitamin C (Ferreira *et al.*, 2021), essential minerals (Alhassan and Ahmed, 2016), and various phytochemicals (Iwansyah *et al.*,

2021), which may improve nutrient utilization and physiological condition (Yan *et al.*, 2013), thereby supporting growth performance in aquatic animals (Maulianawati *et al.*, 2025).

These compounds may promote growth by improving digestive efficiency, nutrient assimilation, antioxidant capacity, and metabolic performance. Similar growth-promoting effects of plant-derived phytobiotics, including *A. bilimbi*, have been reported in several aquaculture species such as Nile tilapia (Rarassari *et al.*, 2025), common carp (Nguyen *et al.*, 2022), Catfish (Agustina *et al.*, 2017), rohu (Debnath *et al.*, 2025), and *Penaues monodon* (Maulianawati *et al.*, 2025). Nevertheless, because digestive enzymes, antioxidant biomarkers, and metabolic responses were not directly measured, the mechanisms underlying the observed growth improvement remain hypothetical and require further investigation.

Influence of dietary protein variation

Proximate analysis revealed slight differences in dietary protein content among treatments, although the variation was relatively small, at approximately 1.58%. Therefore, the improved growth performance observed in fish fed *A. Bilimbi*-supplemented diets was likely associated with both minor nutritional differences and the bioactive compounds present in the extract, including flavonoids, alkaloids, saponins, and antioxidant compounds.

Previous studies have reported that these phytochemicals can improve digestive efficiency, antioxidant capacity, nutrient utilization, and metabolic performance in fish in previous studies (Reverter *et al.*, 2014; Awad and Awaad, 2017; Tadese *et al.*, 2022). However, because the experimental diets were not strictly isonitrogenous, the observed improvement cannot be attributed solely to the bioactive compounds of *A. bilimbi* extract. The growth response should therefore be interpreted as a combined effect of dietary formulation and *A. bilimbi* supplementation rather than an effect of the phytochemicals alone. Plant-derived feed additives, including *A. bilimbi*, have also been reported to enhance antioxidant activity

and stimulate fish growth, particularly during early developmental stages (Xavier *et al.*, 2021; Rarassari *et al.*, 2025).

Dose–response relationship and optimal inclusion level

The results identified 3% *A. bilimbi* extract supplementation (P2) as the most effective inclusion level under the present experimental conditions. Both the lower concentration (P1) and the higher concentration (P3) resulted in a relative lower growth performance and feed efficiency. This pattern suggests a possible dose-dependent response, in which a moderate inclusion level supplies sufficient bioactive compounds to support growth, whereas a lower level may be insufficient and a higher level may reduce performance.

The reduced performance at the highest inclusion level may be related to reduced palatability, the presence of antinutritional compounds, or increased metabolic burden. However, these explanations remain speculative because feed intake, palatability, antinutritional factors, and digestive enzyme activity were not measured in the present study (Reverter *et al.*, 2014). This phenomenon suggests a dose–response relationship, in which both insufficient and excessive supplementation levels may hinder optimal growth performance. These results are consistent with previous studies reporting that dietary supplementation of *A. bilimbi* at moderate inclusion levels can enhance fish growth performance. Several studies have demonstrated that supplementation of *A. bilimbi* extract at 1–3% improved growth performance in tilapia (Hossain *et al.*, 2018). Meanwhile, the optimal supplementation level of *A. bilimbi* extract has been reported to range from 0.5–1.5% in common carp (Nguyen *et al.*, 2022) and at moderate inclusion levels in catfish (Adebayo *et al.*, 2019). Rarassari *et al.* (2025) also reported that 7.5% v/w *A. bilimbi* extract improved growth performance and resulted in 100% survival in tilapia seed. These findings suggest that the response to *A. bilimbi* supplementation may depend on fish species, plant part, extract form, inclusion level, and feeding duration. Under the present experimental conditions,

the 3% w/w inclusion level showed better growth performance than the other tested levels, although further studies are needed to confirm the optimal dose for *R. maninjau*.

CONCLUSIONS

Supplementation of cucumber tree (*A. bilimbi*) leaf extract in feed significantly enhanced the growth performance of *R. maninjau* ($p < 0.05$), while no significant effect on survival rate was observed ($p > 0.05$). The optimal supplementation dose was approximately 3% (P2), with lower or higher doses showing lower growth efficacy. *A. bilimbi* may be effective as a natural feed supplement to improve *R. maninjau* growth, possibly due to its bioactive compound content and the slight increase in dietary protein level.

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