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Utilization of *Eucheuma cottonii* Meal as a Functional Feed Additive for Improving Pigmentation, Health, and Growth in Ornamental Goldfish (*Carrasius auratus*)

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ABSTRACT

Color enhancement in ornamental fish is an essential quality parameter that directly influences market value and consumer preference. Natural pigments derived from marine resources, such as seaweed, offer a sustainable alternative to synthetic color enhancers. This study aimed to determine the effect of seaweed meal (*Eucheuma cottonii*) on the color brightness of goldfish (*Carassius auratus*). Goldfish used had an initial weight of 10.12 ± 0.06 g and an initial length of 5.08 ± 0.02 cm. Fish were fed using the ad libitum method three times daily with four feed treatments: P1 (Control), P2 (4 g seaweed meal), P3 (8 g seaweed meal), and P4 (12 g seaweed meal). The study was conducted for 45 days to evaluate growth performance and color characteristics. A completely randomized design with four treatments and three replications was applied. Data were analyzed using one-way ANOVA at a 95% confidence level ($p < 0.05$). Results showed that the addition of seaweed meal significantly influenced the red hue variable in goldfish. Brightness showed no significant difference among treatments, with the highest value in P4 (55.88%) and the lowest in P3 (52.68%). The red hue differed significantly, with the highest value in P3 (16.96%) and the lowest in P1 (9.13%). The yellow hue showed no significant difference, with values ranging from 36.68% (P1) to 38.43% (P2). Overall, supplementation with 8 g of seaweed meal effectively enhanced the visual red hue of goldfish.

INTRODUCTION

Indonesia has a rich potential in aquatic resources, characterized by its uniqueness and abundance of ornamental fish species, earning it the nickname "home for hundreds of exotic ornamental fish species". There are 240 species of live marine ornamental fish and 226 species of live freshwater ornamental fish (Novák *et al*., 2025). One of the most popular ornamental fish species among the public is the goldfish (*Carassius auratus*), because this ornamental fish has different aesthetic values that can be observed from its color and body shape (Blanco & Unniappan, 2022).

The main attraction of goldfish can be determined by several characteristics, namely color, shape, and size. Its round and unique body shape, bright and cute colors, and the belief that it can bring energy and luck make goldfish the most popular ornamental fish, collected and even competed (Ministry of Marine Affairs and Fisheries, 2019). In addition to physical completeness, agile and healthy fish behavior will also show a bright skin or scale appearance. The main constraint and often faced by ornamental fish breeders is the fading of fish color if kept for a long time in ponds or aquariums (Lau *et al*., 2023).

Color is an aesthetic value of ornamental fish that affects its economic value. Feed nutrition engineering is one way to maintain the color quality of ornamental fish. Color changes often occur due to changes in pigment levels. This is caused by sunlight, water, and feed quality content. The main factor determining the success of goldfish cultivation is feed quality, because it affects growth, color formation, and survival, so it is necessary to provide feed that can support color appearance (Sathyaruban *et al*., 2021). Feed for ornamental fish should contain supplements to improve and enhance color quality. To achieve a balanced nutrition in feed, it is better to use plant-based (plant protein) and animal-based (animal protein) protein simultaneously (Langyan *et al*., 2022).

Seaweed (*Eucheuma cottonii*) is a species of seaweed that is widely cultivated in Indonesian waters. Seaweed is used as an additional ingredient in fish feed because it contains many minerals and good nutritional content for fish growth itself (Siddik *et al*., 2023). The nutritional content of seaweed can vary depending on the type and processing. Seaweed (*Eucheuma cottonii*) contains 9.76% protein; 1.10% lipid; 26.49% carbohydrate; 46.19% ash; 5.91% crude fiber; 10.55% water (Matanjun *et al.*, 2009), and 42−44% carrageenan (Mochtar *et al*., 2013). In addition, seaweed (*Eucheuma cottonii*) contains carotenoids that can affect fish color. According to research by (Minsas *et al*., 2023), the average carotenoid content in seaweed (*Eucheuma cottonii*) ranges from 0.275 to 0.337 mg/g, with the highest carotenoid content of 0.337 mg/g found at a depth of 90 cm.

Seaweed is developed evenly throughout the Indonesian region. One of the regions that is a center for seaweed development is West Nusa Tenggara (NTB). Data from the NTB Marine and Fisheries Agency (2016) shows that seaweed production in 2015 increased by about 19.6% from the previous year. This increase was influenced by the even distribution of seaweed cultivation in NTB across all districts, including East Lombok Regency. According to data from the East Lombok Marine and Fisheries Agency (2016), East Lombok Regency has a marine area of about 1,074.33 km^2 with a potential seaweed cultivation area of 2,000 ha in 2014.

The purpose of this research is to determine the effect of seaweed meal as a combination feed on the brightness level of goldfish color. The research results are expected to be applied to freshwater ornamental fish breeders using seaweed meal with the appropriate dosage to enhance the brightness of goldfish color.

METHODS

Time and place

The research was conducted over a 3-month period, from March to May 2024, at the Fisheries and Aquaculture Laboratory, Faculty of Agriculture, University of Mataram. The activities were carried out in several stages, including preparation, fish rearing, data collection, data analysis, and reporting.

Research Method

This study utilized a laboratory experimental method. The experimental design applied was a Completely Randomized Design (CRD) with four treatments and three replications. All treatments involved the incorporation of different levels of *E. cottonii* meal into commercial fish pellets. The selection of treatment doses was based on previous findings indicating that seaweed-derived bioactive compounds—particularly carotenoids, chlorophylls, and phycobiliproteins—can enhance pigmentation in ornamental fish when included at low to moderate dietary levels. Several studies have demonstrated that *Eucheuma* spp. and other red seaweeds effectively improve fish coloration within inclusion ranges of 1–10%, without compromising growth or feed intake. Rama Nisha et al., (2014) reported improved color intensity in goldfish fed diets containing 2–6% red seaweed meal. Sathyaruban et al., (2021) also observed increased carotenoid deposition in tilapia using 5–10% *Eucheuma cottonii* meal. Similarly, Maiti et al., (2017) found that supplementation of 4–8% red seaweed enhanced redness in koi carp, while Nair et al., (2025) showed that phycobiliproteins from red algae improved pigmentation in ornamental gourami. Studies by Afonso & da Silva Mouga, (2019) and Sinha et al., (2026) further support that seaweed-based pigments act as natural color enhancers across various ornamental species.

Based on these findings, treatment doses in this study were set within the effective inclusion range to evaluate their impact on color performance while maintaining nutritional balance. The treatments were:
P0: Commercial pellet without the addition of *E. cottonii* meal;
P1: Commercial pellet with the addition of 4 grams *E. cottonii* meal;
P2: Commercial pellet with the addition of 8 grams of *E. cottonii* meal;
P3: Commercial pellet with the addition of 12 grams of *E. cottonii* meal.

The experimental setup included 12 glass aquariums measuring 50x30x30 cm, each equipped with an aeration system and a water heater. Rearing used were goldfish (*Carrasius auratus*) with an initial body weight of 3.48±0.04 g and a length of 4.15±0.03 cm. The prawns were stocked at a density of 10 individuals per aquarium. Commercial feed containing 35% protein was provided ad libitum three times daily (morning, noon, and evening). The rearing period for this experiment lasted 35 days.

Feed Formulation

The experimental feed used in this study was a formulated, manufactured feed. The mixed feed was moistened with sufficient hot water, thoroughly mixed, and steamed for 20 minutes. The resulting feed was then pelletized using a grinder. Finally, the pellets were sun-dried until completely dry.

Table 1. Feed Formulation

Raw Material	Feed (g)			
	P0	P1	P2	P3
Eucheuma cottonii meal	0	4	8	12
Commercial pellet	100	96	92	88
Total	100	100	100	100

The fish were reared for 30 days in 12-liter container tanks. Feeding was conducted three times daily at 08:00, 12:00, and 17:00. Tank cleaning and water changes were performed every morning before feeding.

RESULTS

Table 2. The Effect of the Addition *E. cottonii* Meal on Feed for Color Brightness Parameters (L, a, b) of Goldfish (*Carassius auratus*)

Parameters	***Eucheuma cottonii* Meal Composition (g)**			
	P0 (Control)	**P1 (4 g)**	**P2 (8 g)**	**P3 (12 g)**
Lightness (L)	54.79	53.15	52.68	55.88
Reddness (a)	9.13	16.10	16.96	13.03
Yellowness (b)	36.68	38.43	36.97	37.71

The addition of *E. cottonii* meal to the feed of goldfish (*Carassius auratus*) showed varying effects on the color parameters (L, a, and b). The lightness (L) value decreased from the control to the 8 g dose but increased again at the 12 g dose, indicating that the highest brightness was obtained in treatment P3. The redness (a) parameter increased sharply at the 4 g dose and reached its peak at the 8 g dose before declining at 12 g, suggesting that 8 g is the most optimal level for enhancing red coloration. Meanwhile, the yellowness (b) value tended to increase compared to the control across all treatments, with minor fluctuations between the 4–12 g doses. Overall, supplementation with *E. cottonii* meal was able to improve the color intensity of goldfish, particularly the red and yellow components, although the highest response was dose-dependent.

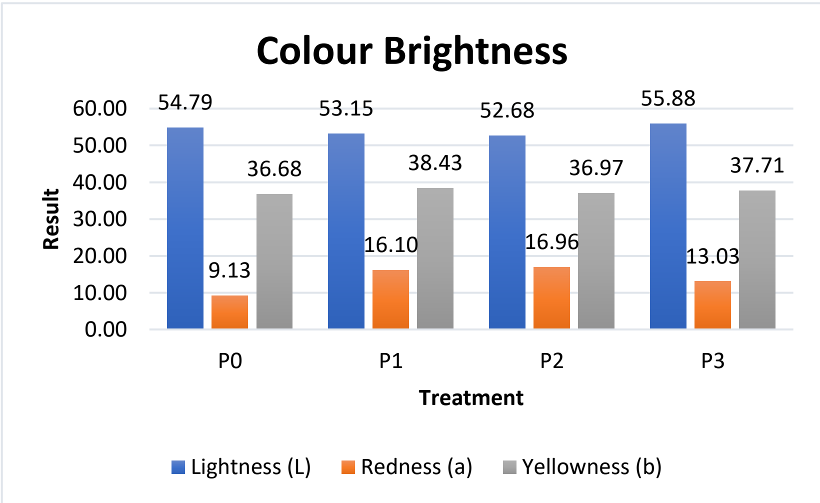

Figure 1. Different Treatment of Adding *E. cottonii* Meal on Feed

The graph shows that the addition of *E. cottonii* meal to goldfish feed produces different changes in the color brightness parameters (L, a, and b). The lightness (L) value tends to decrease from the control (P0) to treatment P2, but increases sharply in P3, indicating that the 12 g treatment produced the highest brightness level. The redness (a) parameter increased significantly in P1 and reached its peak in P2 before declining in P3, suggesting that the 8 g dose was the most effective in enhancing red color intensity. Meanwhile, the yellowness (b) value was generally higher in treatments supplemented with *E. cottonii* compared to the control, with slight fluctuations in P2 and a subsequent increase in P3. Overall, supplementation with *E. cottonii* meal was shown to enhance fish coloration, particularly the red and yellow components, although its effectiveness varied depending on the dosage applied.

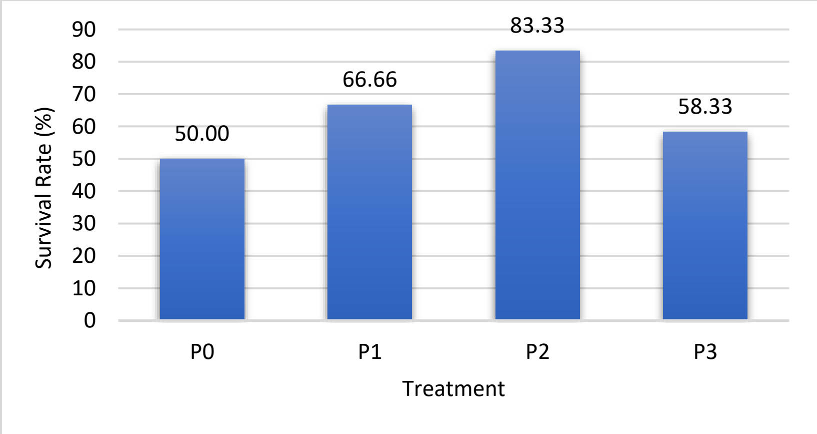

Figure 2. Effect of *E. cottonii* Meal Supplementation in Feed on the Survival Rate of Goldfish

The graph shows that the survival rate of goldfish increased with the addition of *E. cottonii* meal in the feed, but only up to a certain dosage. In the control treatment (P0), the survival rate was recorded at 50%, then increased in P1 to 66.66% and reached its highest value in P2 at 83.33%, indicating that the 8 g dose can be considered the most effective treatment for maintaining fish survival. However, in P3 (12 g), the survival rate decreased to 58.33%, suggesting that excessively high doses of *E. cottonii* meal no longer provide positive effects and may even reduce fish survivability. Overall, supplementation with *E. cottonii* was shown to improve the survival of goldfish, although its effectiveness depends on the appropriate dosage applied.

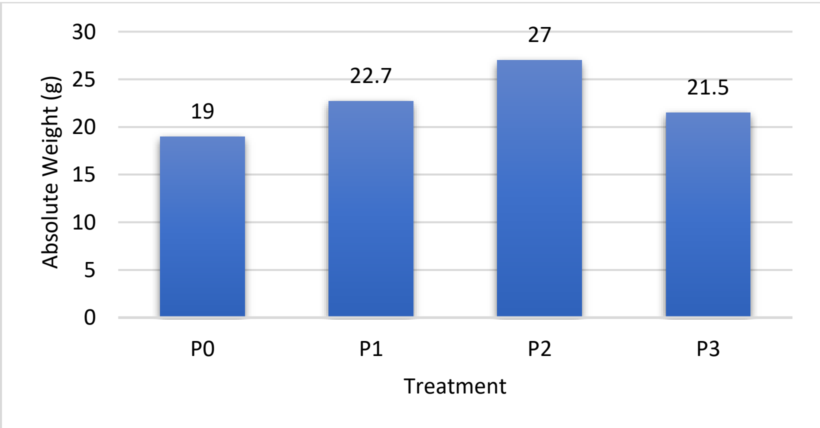

Figure 3. Effect of *E. cottonii* Meal Supplementation in Feed on Absolute Weight (g) of Goldfish

The graph shows that the addition of *E. cottonii* meal in the feed affected the absolute weight gain of goldfish. The control treatment (P0) produced the lowest weight gain at 19 g, which then increased in P1 to 22.7 g and reached the highest value in P2 at 27 g, indicating that the supplementation of 8 g of *E. cottonii* was the most optimal for enhancing fish weight growth. However, in P3 with a 12 g dose, the absolute weight gain decreased again to 21.5 g, showing that excessively high doses of *E. cottonii* meal no longer support growth and may even reduce weight-gain performance. Overall, supplementation with *E. cottonii* was able to improve fish growth, but its effectiveness was strongly influenced by the dosage, with the best results obtained in the P2 treatment.

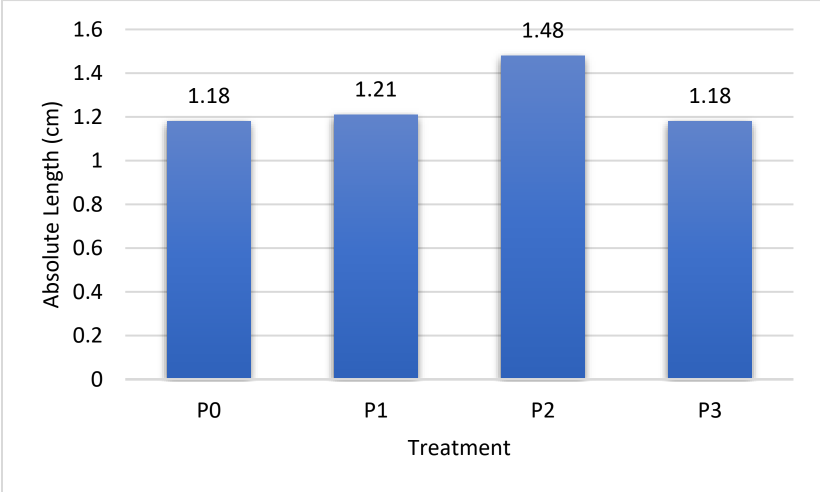

Figure 4. Effect of *E. cottonii* Meal Supplementation in Feed on Absolute Length (cm) of Goldfish

The graph shows that supplementation of *E. cottonii* meal in the feed influenced the absolute length growth of goldfish. The control treatment (P0) produced a length increase of 1.18 cm, which increased slightly in P1 to 1.21 cm. The highest value was achieved in P2, at 1.48 cm, indicating that the 8 g dose of *E. cottonii* was the most effective in stimulating length growth. However, in P3, the length increase decreased again to 1.18 cm, equal to the control, showing that excessively high doses no longer provide growth benefits. Overall, *E. cottonii* was able to enhance the length growth of goldfish, but its effectiveness depended on the dosage, with optimal results observed in the P2 treatment.

Table 3. Water Quality During the Research

Parameters	**Treatment**			
	P0 (control)	**P1 (4 g)**	**P2 (8 g)**	**P3 (12 g)**
Temperature (°C)	25.7 – 27.5	25.9 – 27.1	25.7 – 26.9	25.8 – 27.0
DO (mg/l)	3.1 – 3.4	3.0 – 3.4	3.0 – 3.6	3.0 – 3.4
pH	7.39	7.21	7.10	7.22

Water quality during treatments (P0–P3) were within ranges that still support the survival of cultured aquatic organisms. The water temperature of 25.7–27.5°C is considered ideal for most tropical aquaculture species, thus preventing thermal stress. The dissolved oxygen (DO) level, ranging from 3.0–3.6 mg/L, is relatively low but still within the tolerance limits of several species capable of living in environments with moderate oxygen levels; however, this condition indicates the need for aeration to maintain optimal performance. The pH values of 7.10–7.39 also fall within the optimal range for physiological processes in aquatic organisms, including metabolism and ionic balance. Overall, the stable values of temperature, DO, and pH across treatments indicate that the addition of treatment doses did not produce significant impacts on water quality, suggesting that the biological responses of the organisms were more likely influenced directly by the treatments themselves rather than by environmental changes in the culture medium.

DISCUSSION

In the context of the ornamental aquaculture industry, enhancement of color intensity represents a key indicator of product quality because it directly influences consumer value perception and market price. The use of *E. cottonii* as a feed additive holds significant potential as a value-adding strategy, considering that this seaweed resource is abundant, low-cost, and sustainably producible. Natural pigments are more widely accepted in global markets compared to synthetic pigments, thereby providing competitive advantages and aligning with consumer preferences for environmentally friendly product (Dave *et al*., 2022). Thus, the integration of *E. cottonii* into feed formulations not only scientifically enhances the aesthetic performance of ornamental fish but also strengthens the commercial position of producers within the ornamental aquaculture value chain.

Supplementation of *E. cottonii* meal in the diet produced significant responses in color brightness parameters (L*, a*, b*) of goldfish (*Carassius auratus*). The marked increase in (a*) redness observed in treatments P1 and P2 (16.10 and 16.96) compared to the control (9.13) indicates enhanced carotenoid deposition in chromatophores, particularly erythrophores responsible for red coloration. This is consistent with reports showing that *E. cottonii* contains carotenoid pigments and phycobiliproteins that can act as precursors for color development in ornamental fish (Holdt & Kraan, 2011; Reddy *et al*., 2008). The reduction in lightness (L*) in P1 and P2 further demonstrates that increased pigmentation strengthens hue intensity, making the fish appear richer and more contrasted—an established indicator of successful pigment supplementation in ornamental aquaculture.

The (b*) yellowness parameter increased in P1 and P3, indicating that *E. cottonii* meal also enhances the accumulation of xanthophyll pigments contributing to yellow hues. Treatment P2 yielded the highest (a*) redness value, suggesting that an 8-g dose provides optimal efficiency for pigment absorption and deposition, likely due to a balance between nutrient availability and the fish's metabolic capacity to translocate carotenoids into dermal tissues. This phenomenon aligns with findings by (Nowacka *et al*., 2021), who stated that color response typically peaks at moderate pigment doses before declining due to physiological limitations in absorption. Overall, the response patterns of (a*) redness and (b*) yellowness demonstrate that *E. cottonii* functions effectively as a natural pigment source in ornamental fish diets.

The data also show that goldfish survival rates increased with *E. cottonii* supplementation, peaking in treatment P2 (83.33%), substantially higher than the control (50%). This improvement is likely associated with the bioactive compounds in *E. cottonii*, particularly antioxidants such as carotenoids, phenolics, and sulfated polysaccharides, which are known to enhance non-specific immune responses in fish (Siddik *et al*., 2023 & da Silva Brito, 2021). Additionally, the soluble fiber and hydrocolloids present in *E. cottonii* may promote gastrointestinal health, enhance nutrient absorption efficiency, and maintain gut microbiota stability, collectively contributing to improved resistance against environmental stress and pathogens. This explains why P2 exhibited the optimal survival rate, while excessive doses in P3 led to reduced performance.

The survival rate pattern indicates that moderate supplementation produces the most favorable outcomes, consistent with aquaculture nutrition principles in which increasing additive levels does not always generate linear responses and may induce saturation effects or metabolic disturbances at higher doses (Tacon & Metian, 2013). Treatments P1 and P3 showed higher survival than the control but lower than P2, demonstrating that *E. cottonii* has an effective dose range. In ornamental fish culture, high survival rates reflect not only successful dietary formulation but also environmental stability, immune performance, and production sustainability. These data suggest that *E. cottonii* supplementation at optimal levels represents a nutritional strategy supporting fish health without significantly increasing operational costs.

In the ornamental fish industry, high survival rates substantially affect production efficiency by reducing mortality, which is a major source of financial loss. Treatment P2, with a survival rate of 83.33%, offers considerable business implications: the more individuals that survive to marketable size, the greater the potential profit margin. Feed containing *E. cottonii* also provides added market value as a “functional feed,” increasingly sought after due to associations with improved fish health, enhanced coloration, and environmental sustainability. Global market trends show rising demand for ornamental fish products supported by environmentally friendly nutritional technologies (Calado *et al*., 2017). Therefore, the application of *E. cottonii* in feed formulation not only improves biological performance but also strengthens the competitiveness and commercial positioning of aquaculture enterprises.

The growth data demonstrate a consistent biological response between increases in absolute weight and absolute length of goldfish under *E. cottonii* supplementation. Treatment P2 produced the highest values for both parameters (27 g and 1.48 cm), followed by P1, whereas P0 and P3 exhibited lower responses. This parallel pattern indicates a positive linear correlation between the two growth parameters, which in fish physiology often reflects improved nutrient utilization efficiency. This mechanism is likely influenced by the bioactive components of *E. cottonii*, such as sulfated polysaccharides, minerals, and antioxidants, which enhance metabolic performance, immune function, and gut microbiota balance across various fish species (Chen *et al*., 2021; Omont *et al*., 2019).

Biologically, the relationship between weight and length gain aligns with the isometric growth model in fish, in which accelerated linear growth expands tissue-building capacity, thereby supporting simultaneous increases in body mass when nutrient supply is sufficient. The optimal response in P2 indicates that *E. cottonii* supplementation reached a physiological efficiency threshold, while the decline observed in P3 suggests potential saturation or energy dilution effects, consistent with the concept that excessive dietary fiber or structural components can reduce net energy availability and impair growth performance (Roleda & Hurd, 2019). Thus, the parallel relationship between both growth parameters indicates that *E. cottonii* modulates anabolic processes harmoniously up to an optimal dosage.

From an aquaculture business perspective, the positive correlation between weight and length gains at optimal supplementation levels has significant implications for production efficiency and profitability. Faster growth reduces culture duration, improves Feed Conversion Ratio (FCR), and increases production turnover. Additionally, the use of *E. cottonii* as a locally sourced feed additive can reduce reliance on imported ingredients and support integrated seaweed–fish farming, consistent with the IMTA (Integrated Multi-Trophic Aquaculture) concept. Industry studies have shown that macroalgae-based feed additives enhance feed efficiency and stress tolerance, thereby providing competitive advantages for producers (Charoensook *et al.*, 2021). Thus, the strong correlational relationship between growth parameters in this study provides both scientific and strategic justification for the incorporation of *E. cottonii* into commercial feed formulations.

CONCLUSION

Supplementation of *E. cottonii* proved effective in improving color quality, growth, and survival of goldfish through enhanced pigment deposition, strengthened metabolic performance, and immune stimulation at a dosage of 8 g per 100 g of feed. Improvements in redness (a*) and yellowness (b*) indicate efficient carotenoid and xanthophyll deposition, confirming the role of *E. cottonii* as a natural pigment source in ornamental fish diets. The highest survival and growth outcomes at moderate supplementation levels suggest that E. cottonii provides bioactive benefits, including antioxidant support and improved nutrient utilization, while excessive doses may reduce overall performance. This synergy of physiological benefits demonstrates that *E. cottonii* functions as a comprehensive functional feed additive, significantly supporting the biological performance of the fish.

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