Journal of Academic Biology and Biology Education
Vol. 2, No. 2, December 2025, pp. 157~164
ISSN: 3062-9705, DOI: 10.37251/jouabe.v2i2.2243

Roselle (*Hibiscus sabdariffa*) as a Sustainable Herbal Supplement for Enhancing the Performance of Freshwater Ornamental Fish

Muhammad Ijaz[1], Setyawan Heru Tandyo[2]
[2]Department of Biology, Prince of Songkla University, Songkhla, Thailand
[3]Biology Study Program, Universitas Islam Negeri Syarif Hidayatullah Jakarta, South Tangerang City, Indonesia

Article Info

Article history:

Received Oct 17, 2025
Revised Nov 27, 2025
Accepted Dec 12, 2025
Online First Dec 24, 2025

Keywords:

Feed Supplementation
Immunity
Ornamental Fish
Pigmentation
Roselle (*Hibiscus sabdariffa*)

ABSTRACT

Purpose of the study: The purpose of this study is to examine the effect of roselle (*Hibiscus sabdariffa*) supplementation on the performance of ornamental fish, including growth rate, survival rate, feed intake, and body pigmentation, through a systematic review of national and international research findings.

Methodology: This study employed a literature review method using Google Scholar, ScienceDirect, and ResearchGate databases. Data were analyzed descriptively using Microsoft Excel 2021. Reference validation was based on ISSN and DOI verification. Literature selection, classification, and data extraction were performed systematically following PRISMA guidelines to ensure research reliability.

Main Findings: The main findings show that Roselle (*Hibiscus sabdariffa*) contains bioactive compounds such as anthocyanins, flavonoids, and vitamin C that enhance fish health and immunity. Supplementation improved survival rate and feed intake but did not significantly increase color performance, as anthocyanins are not dominant pigments for coloration compared to carotenoids like astaxanthin and zeaxanthin.

Novelty/Originality of this study: This study provides new insight into the potential use of Roselle (*Hibiscus sabdariffa*) as a natural feed additive for ornamental fish. Unlike previous studies focused on food fish, it highlights Roselle's bioactive compounds in enhancing immunity and feed intake, offering an eco-friendly alternative to synthetic additives in sustainable aquaculture practices.

Corresponding Author:
Setyawan Heru Tandyo
Biology Study Program, Universitas Islam Negeri Syarif Hidayatullah Jakarta, Jl. Ir H. Juanda No. 95, Ciputat, East Ciputat District, South Tangerang City, Banten 15412, Indonesia
Email: tandoyo77@gmail.com

1. INTRODUCTION

The ornamental fish industry is one of the fastest-growing sectors in global aquaculture. The demand for ornamental fish continues to rise in line with economic growth, public interest in the hobby, and the expansion of export markets [1], [2]. Thailand is recognized as one of the world's leading producers and exporters of freshwater ornamental fish, particularly species such as *Betta splendens* (Siamese fighting fish), *Poecilia reticulata* (guppy), and *Carassius auratus* (goldfish) [3], [4]. This sector not only contributes significantly to the economy but also plays an important role in improving community welfare and diversifying aquaculture commodities.

However, despite its great economic potential, the ornamental fish industry faces several challenges, particularly in improving fish performance, which includes growth, stress tolerance, immunity, and body color quality. Factors such as feed quality, environmental conditions, and the use of feed additives greatly influence fish performance [5], [6]. The use of synthetic substances such as antibiotics and color-enhancing hormones is still common in some areas, even though they are known to cause adverse effects on fish health, the environment, and consumer safety [7], [8]. Therefore, more environmentally friendly and sustainable approaches are needed to enhance ornamental fish performance, one of which is through the utilization of natural materials derived from medicinal plants.

Herbal plants have been widely used in aquaculture as immunostimulants, antioxidants, and growth and color enhancers. Various studies have shown that natural ingredients such as *Curcuma longa* (turmeric), *Azadirachta indica* (neem), and *Spirulina platensis* can enhance the immune system, feed efficiency, and body coloration in fish [9], [10]. The use of medicinal plants as natural additives in fish feed is considered one of the key strategies for achieving sustainable aquaculture practices.

One of the promising herbal plants for aquaculture development is roselle (*Hibiscus sabdariffa*). Roselle has been widely known in various tropical countries, including Thailand, for its rich phytochemical content and numerous health benefits [11], [12]. Roselle contains anthocyanins, flavonoids, ascorbic acid, and phenolic compounds with high antioxidant activity [13], [14]. These compounds play an important role in reducing oxidative stress, strengthening the immune system, and improving metabolic processes in aquatic organisms.

Previous studies have shown that roselle extract or powder can enhance growth, feed efficiency, and immune responses in cultured fish such as *Oreochromis niloticus* (Nile tilapia) and *Clarias gariepinus* (African catfish). Moreover, the anthocyanin content in roselle can serve as a natural pigment source, which has the potential to improve the body coloration of ornamental fish an essential parameter determining their market value [15], [16]. However, studies on the application of roselle in freshwater ornamental fish are still very limited, particularly in Thailand. Few investigations have explored in depth the effects of roselle supplementation on the growth performance, coloration, and immunity of ornamental fish under tropical aquaculture conditions.

Most previous studies have focused on food fish rather than ornamental species and have primarily emphasized growth and immunity aspects without evaluating changes in body coloration and aesthetic quality. Furthermore, no comprehensive study in Thailand has yet examined the effects of roselle supplementation on freshwater ornamental fish performance under controlled conditions. Scientific data regarding the optimal dosage, physiological parameters, and antioxidant effects of roselle on ornamental fish remain limited. Therefore, further research is needed to fill this knowledge gap.

This study is of high importance because the use of natural materials such as roselle (*Hibiscus sabdariffa*) to improve the performance of freshwater ornamental fish has not been widely explored, especially in Thailand—one of the world's largest ornamental fish producers. The use of synthetic feed additives remains a common practice, even though it may have negative impacts on fish health, the environment, and production sustainability. Hence, a natural, safe, effective, and locally available alternative is needed. Roselle, rich in bioactive compounds, has great potential as a multifunctional natural ingredient to improve the growth, survival, and pigmentation of ornamental fish. This research is essential to provide a scientific basis for the development of herbal-based feeds that support sustainable aquaculture practices and enhance the competitiveness of Thailand's ornamental fish industry in the global market. This study aims to determine the effects of roselle (*Hibiscus sabdariffa*) supplementation on weight gain, survival rate, and feed consumption of ornamental fish, as well as its influence on body pigmentation improvement.

2. RESEARCH METHOD

In this study, the method used was a literature review by collecting data from various academic sources. The data collection process involved recording, reading, and processing research materials. Data extraction was conducted following PRISMA 2020 guidelines, applying inclusion criteria such as experimental design, peer-reviewed publication, and relevance to ornamental fish performance. Studies lacking DOI or ISSN validation were excluded. Descriptive statistical analysis and synthesis were performed using Microsoft Excel 2021.

This research was conducted through a systematic and structured literature review. First, literature related to the chemical and phytochemical composition of roselle (*Hibiscus sabdariffa*) applied as a supplementation material in ornamental fish was collected. Second, the search focused on studies that evaluated the effects of roselle compounds on ornamental fish performance. Third, both international and national research findings were organized chronologically based on publication year, and data were extracted regarding performance parameters such as weight gain, survival rate, feed intake, and changes in body pigmentation or coloration. Fourth, all findings were summarized and analyzed to identify variations in methods, dosages, outcomes, and research gaps. Fifth, based on the synthesis of the available evidence, a formulation was

developed regarding the effectiveness of roselle compounds in enhancing ornamental fish performance. Finally, conclusions were drawn summarizing the theoretical and practical implications, along with recommendations for further experimental research.

The data analysis method used in this study was descriptive. To ensure the relevance of the collected data to the research topic, a selection process was conducted. The journal articles obtained were screened, compiled, and reviewed. The scope of data presented in the discussion table was limited to sources downloaded exclusively from official websites. Subsequently, the collected data were categorized into patterns, themes, or basic descriptive units. Any data unrelated to the research topic or lacking validation were excluded from the analysis.

3. RESULTS AND DISCUSSION

Roselle contains active compounds that can help improve fish health by enhancing the immune system, preventing bacterial infections, and promoting color enhancement and growth. The complete composition of roselle is presented in the following Table 1.

Table 1. Composition of Roselle (*Hibiscus sabdariffa*) Petal Powder

Component	Amount/100 g	References
Anthocyanin	355 mg	Pérez-Escalante et al. [16]
Vitamin C	2033.52 mg	
Lycopene	164 µg	
Ascorbic acid	11 mg	
Iron	25 mg	
Carotene	0.03 mg	
Thiamine	0.117 mg	Islam et al. [17]
Riboflavin	0.6 mg	
Niacin	3.7 mg	

The highest compound content in roselle (*Hibiscus sabdariffa*) petal powder is Vitamin C, with a concentration of 2033.52 mg per 100 g of roselle petal powder. Vitamin C plays an essential role as a powerful antioxidant defense system in fish. Based on results from several controlled studies and field observations, dietary supplementation with Vitamin C above the level recommended for optimal growth has been proven effective in providing additional protection for the fish immune system under stressful conditions [18].

Anthocyanins and carotenoids are compounds contained in roselle that are believed to influence pigmentation in ornamental fish. Anthocyanins are natural pigments with antioxidant properties and are commonly found in various parts of plants. They are organic compounds belonging to the flavonoid group and are classified as polyphenolic compounds [19], [20].

Carotene is a natural pigment found in various types of plants, algae, and bacteria. This pigment is responsible for the bright red, orange, and yellow coloration observed in many ornamental fish species. Carotenoids are not synthesized by fish but are obtained through their diet. Several studies have investigated the effects of carotenoid supplementation in ornamental fish. For instance, a study published in the *Aquaculture* journal reported that feeding diets supplemented with carotene resulted in increased growth rate, improved survival, and enhanced coloration [21], [22].

According to Sholichah et al. [23] and Pérez-Escalante [16], roselle (*Hibiscus sabdariffa*) petal powder has an effect on the performance of ornamental fish such as goldfish (Table 2) and koi (Table 3). The performance parameters influenced include body weight gain, survival rate, and feed intake.

Table 2. Effect of Roselle (*Hibiscus sabdariffa*) Concentration Variations on Goldfish (*Carassius auratus*)

	Roselle Concentration in Feed (mg/kg)			
	0	40	80	160
Survival (%)	90.00	96.6	96.6	96.6
Weight gain (g)	11.70	14.08	11.69	13.3
Feed intake (g)	42.08	47.11	40.70	44.84

In 2011, Verónica Pérez-Escalante conducted a study using goldfish (*Carassius auratus*) as the test subjects. The research applied four different concentrations of roselle (*Hibiscus sabdariffa*) powder in fish feed. The goldfish were reared for eight weeks and fed diets supplemented with roselle powder at doses of 0, 40, 80, and 160 mg/kg of feed.

Table 3. Effect of Roselle (*Hibiscus sabdariffa*) Concentration Variations on Koi Fish (*Cyprinus carpio*)

	Roselle Concentration in Feed (mg/kg)			
	0	500	1000	1500
Survival (%)	56.67	63.33	93.33	83.33
Weight gain (g)	0.49	0.72	1.15	0.99
Feed intake	3	3	4	4

Note: Feed intake score: 1 = Feed not eaten; 2 = Feed slightly eaten; 3 = Most feed eaten; 4 = All feed consumed

The use of roselle as a feed additive has also been tested in a study conducted by Sholichah et al. [23]. The study used koi fish (Cyprinus carpio) as the research subjects. The fish were reared for 84 days and fed diets supplemented with roselle powder at concentrations of 0, 500, 1000, and 1500 mg/kg of feed.

The growth performance of fish fed roselle-supplemented diets at different doses showed inconsistent results and no significant differences. As presented in Table 2, the highest weight gain of 14.08 g was observed in goldfish fed the second treatment (40 mg/kg of feed). Similarly, in Table 3, koi fish fed with 1000 mg of roselle powder per kg of feed showed a weight gain of 1.15 g. The variation in weight gain among fish may be influenced by factors such as fish species, feed quality, environmental conditions, and feeding management. Some fish species have faster growth rates and higher metabolic activity than others, thus requiring more nutrients to support their growth [24].

The addition of roselle to fish feed did not significantly affect weight gain, likely because the dominant compounds in roselle petals possess primarily antioxidant properties. According to Velasco-Santamaría and Corredor-Santamaría [25], fish weight gain is more strongly influenced by the availability of essential nutrients such as protein, fat, and vitamins in the feed. This statement aligns with findings showing that increased fish weight indicates that nutrient requirements—such as protein, carbohydrates, and fat are present at optimal levels in the feed, thereby fulfilling the fish's daily nutritional needs [26], [27].

A proximate analysis of roselle-supplemented feed conducted by Raudhotul reported a favorable **fat** content ranging from 6.2% to 6.8%, since fat levels exceeding 13% may cause fat accumulation and reduce fish appetite [28]. The protein content of the roselle-enriched feed, according to Papillon and Efendi [29] was categorized as good, ranging between 32.8% and 35.7%, consistent with the recommended protein level for quality fish feed (>30%). According to Mukti et al. [30], carbohydrate content consists of indigestible carbohydrates (crude fiber) and digestible carbohydrates (nitrogen-free extract or NFE). Musdalifah et al. [31], stated that the tolerable level of crude fiber in roselle-supplemented feed is 8–12%, indicating that a crude fiber level of 10.1% remains within the safe range.

Based on both studies, roselle supplementation in feed showed that the survival rate did not reach 100%. The survival rate in the first study appeared more stable compared to the second one, yet both were still considered good. This aligns with the findings of [32], which state that a survival rate (SR) ≥ 50% is considered good, 30–50% is moderate, and ≤30% is poor. The anthocyanin concentration in roselle petals was reported to be 3.55 ± 0.35 mg/g.

The most notable characteristic of roselle petals is the presence of bioactive compounds such as anthocyanins, ascorbic acid, flavonoids, and amino acids, which play an important role in stimulating leukocytes as a part of the nonspecific defense system, thus functioning as immunostimulants that can enhance the survival rate of fish against pathogens [33] The red pigment also demonstrates strong antioxidant capacity, and these components can participate in the fish's metabolic processes, thereby promoting better health and growth performance [34].

One mechanism by which anthocyanins may help increase fish antibody levels is by stimulating the production of immune cells, such as lymphocytes and macrophages, which are responsible for fighting infections and diseases within the fish body [35], [36]. Additionally, anthocyanins can help reduce oxidative damage in fish cells. Oxidative damage occurs when free radicals are generated in the fish body due to oxidative stress or unfavorable environmental exposure. Anthocyanins protect cells from oxidative damage by scavenging free radicals and preventing cellular deterioration [37].

Anthocyanins are also found in other Hibiscus species, such as *Hibiscus rosasinensis*. According to Weerasingha [38], he highest roselle anthocyanin content can be extracted using the hot-water extraction method, where 100 g of Hibiscus rosasinensis petals contain 679.3 mg of anthocyanins.

Both studies indicate that the addition of roselle-derived anthocyanins to fish feed can improve feed intake. Table 3 shows that the feed intake levels ranged between 3 and 4, meaning that the feed was almost completely consumed or fully consumed, suggesting that roselle supplementation provides a good level of palatability.Palatability refers to the degree to which a feed is preferred or desired by animals, particularly in livestock or aquaculture contexts. It is influenced by several factors, including the aroma, taste, texture, shape, color, and nutritional composition of the feed. The higher the palatability of a feed, the greater the likelihood that the fish will voluntarily consume it and thus obtain the nutrients necessary for optimal growth and development. The high palatability of roselle-supplemented feed also indicates that diffused anthocyanins from the feed into

the water do not interfere with the fish's chemosensory stimulation, since according to Sihombing et al. [28] the shape and aroma of feed play an essential role in helping fish locate and recognize available food sources.

Fish feeding behavior is highly influenced by the chemical mixture present in the feed, which stimulates the chemosensory cells to trigger a feeding response. Fish exhibit olfactory (smell) and gustatory (taste) sensitivities to feed ingredients that resemble their natural diet. The olfactory system functions as a long-distance sense, providing cues for approaching food, while the gustatory system operates at close range and determines whether the food will be accepted or rejected .

Research has shown that the addition of roselle-derived anthocyanins to fish feed can increase feed consumption. However, it is essential to note that anthocyanin supplementation should not be excessive and must maintain a balanced feed ratio appropriate for the nutritional requirements of ornamental fish. Therefore, anthocyanin supplementation in ornamental fish feed should be administered proportionally and in accordance with fish nutritionist recommendations.

Roselle contains compounds that contribute to pigmentation, namely anthocyanins and carotene (Table 1). According to Pérez-Escalante [16] anthocyanins increased the number of chromatophore cells by up to 200 cells per area, allowing pigmentation to become concentrated in specific regions. Although anthocyanin levels increase within fish tissues, this pigment tends not to be stored in chromatophore cells [39]. nstead, carotenoid groups such as astaxanthin and zeaxanthin are more likely to be stored and converted within the fish body [40], [41]. Nevertheless, anthocyanins still fulfill other vital biological functions, as demonstrated by Dávalos et al. [42] who emphasized their significant role as antioxidant agents..

Table 4. Sources of Carotenoids from Natural Ingredients

No	Source	Fish Species	Dosage	Color Enhancement (%)	Reference
1	Marigold	*Carassius auratus*	150 mg/kg	54.44%	Sukarman et al. [43]
2	Shrimp head powder	*Carassius sp*	100 g/kg	25%	Fitriana et al. [44]
3	Sweet potato	*Melanotaenia praecox*	200 mg/kg	17%	Yaeni et al. [45]
4	Carrot	*Carassius auratus*	5 %, 10 %, 15 % of feed (≈ 50,000 – 150,000 mg/kg)	10–15 % (highest at 10 %)	Dersiani et al. [46]
5	Red spinach	*Puntigrus tetrazona*	60 g/kg	20.57%	Gamel et al. [47]

Table 4 presents previous studies on the use of carotenoids derived from various natural sources to enhance pigmentation in ornamental fish. The highest color enhancement was observed in fish fed diets supplemented with Marigold, showing an increase of 54.44%. This result is attributed to the ability of goldfish (Carassius auratus) to efficiently utilize carotenoid compounds in marigold to improve body pigmentation. This finding is also supported by Yuangsoi et al. [48] , who stated that herbivorous fish species, such as goldfish and koi, are capable of storing lutein, zeaxanthin, and canthaxanthin in their bodies without altering their molecular structures, and can further convert them into astaxanthin.

According to Sukarman et al. [43], color enhancement can be measured using the Lightness, Chroma, and Hue (LCH) method, which is a color quality assessment technique used to quantify specific color parameters of an object. The LCH method consists of three interrelated parameters: Lightness (L), indicating how light or dark a color is, with values ranging from 0 (black) to 100 (white); Chroma (C), representing the saturation or purity of the color, with values ranging from 0 (gray) to 100 (highly vivid color); and Hue (H), which indicates the type of color perceived, such as red, green, or blue, with values ranging from 0 to 360 degrees on the color wheel. Measuring these three parameters allows for a more accurate and objective evaluation of color quality in ornamental fish pigmentation studies.

This study presents a novel contribution by exploring the use of roselle (*Hibiscus sabdariffa*) as a natural feed supplement for freshwater ornamental fish—a field previously dominated by research on food fish species. It broadens scientific understanding of the bioactive compounds in roselle, such as anthocyanins, flavonoids, and vitamin C, which can enhance immune response and feed efficiency in ornamental fish. By synthesizing national and international studies, this research highlights roselle's potential as an eco-friendly alternative to synthetic additives in sustainable aquaculture. Furthermore, it represents one of the first systematic

reviews to integrate evidence on roselle's effects on growth, survival rate, and pigmentation in tropical ornamental fish.

The findings imply that roselle holds great promise as a natural dietary supplement to improve physiological performance and immunity in ornamental fish without harming animal health or the aquatic environment. Its application may support sustainable aquaculture practices and encourage innovation in herbal-based feed production in tropical regions such as Thailand and Indonesia. However, the main limitation of this study lies in its literature-based nature, as no direct experimental validation was conducted to determine the optimal dosage or interactions of roselle's active compounds among different fish species. Therefore, further *in vivo* experimental studies under controlled conditions are strongly recommended to verify these findings and establish the practical effectiveness of roselle supplementation in various aquaculture settings.

4. CONCLUSION

This study concludes that *Hibiscus sabdariffa* (roselle) contains bioactive compounds such as anthocyanins, flavonoids, and vitamin C that can positively influence the health and performance of freshwater ornamental fish. Roselle supplementation improves survival rate, feed intake, and immune response due to its antioxidant and immunostimulant properties. However, the effect on pigmentation performance remains limited, as anthocyanins are not dominant pigments responsible for color enhancement compared to carotenoids such as astaxanthin and zeaxanthin. Overall, roselle demonstrates great potential as a sustainable and eco-friendly herbal supplement to replace synthetic additives in ornamental fish feed. Future studies are recommended to conduct experimental validation on optimal dosage, species-specific responses, and synergistic effects with other natural ingredients to maximize both health and coloration performance in ornamental fish aquaculture.

ACKNOWLEDGEMENTS

The researcher would like to express his gratitude to all parties who supported the completion of this research.

AUTHOR CONTRIBUTIONS

Conceptualization, M.I. and S.H.T.; Methodology, M.I.; Software, M.I.; Validation, M.I. and S.H.T.; Formal Analysis, M.I.; Investigation, M.I.; Resources, S.H.T.; Data Curation, M.I.; Writing – Original Draft Preparation, M.I.; Writing – Review & Editing, M.I. and S.H.T.; Visualization, M.I.; Supervision, S.H.T.; Project Administration, S.H.T.; Funding Acquisition, S.H.T.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

REFERENCES

[1] J. H. Peh and M. N. Azra, "A global review of ornamental fish and shellfish research," *Aquaculture*, vol. 596, p. 741719, 2025, doi: 10.1016/j.aquaculture.2024.741719.

[2] S. H. Hoseinifar *et al.*, "Sustainable ornamental fish aquaculture: the implication of microbial feed additives," *Animals*, vol. 13, no. 10, 2023, doi: 10.3390/ani13101583.

[3] L. Gruneck, V. Jinatham, P. Therdtatha, and S. Popluechai, "Siamese fighting fish (Betta splendens Regan) gut microbiota," *Fishes*, vol. 7, no. 347, 2022, doi: 10.3390/ fishes7060347.

[4] A. Sermwatanakul, "Capacitating the local farmers to enhance global marketing of Thailand's national aquatic animal, the siamese fighting fish," *Fish People*, vol. 17, no. 2, pp. 42–48, 2019.

[5] A. J. Onomu and G. E. Okuthe, "The role of functional feed additives in enhancing aquaculture sustainability," *Fishes*, vol. 9, no. 5, 2024, doi: 10.3390/fishes9050167.

[6] T. Sommuek, K. Kasamawut, P. Ngamsnae, K. Sreeputhorn, and S. Saowakoon, "Impacts of feed additives, prebiotics and vitamin E on growth and reproductive performance of Nile tilapia, Oreochromis niloticus (Linnaeus, 1758)," *J. Fish. Environ.*, vol. 47, no. 3, pp. 1–10, 2023.

[7] P. Islam *et al.*, "Steroid hormones in fish, caution for present and future: A review.," *Toxicol. reports*, vol. 13, p. 101733, Dec. 2024, doi: 10.1016/j.toxrep.2024.101733.

[8] C. Au-Yeung *et al.*, "Antibiotic abuse in ornamental fish: an overlooked reservoir for antibiotic resistance," *Microorganisms*, vol. 13, no. 4, Apr. 2025, doi: 10.3390/microorganisms13040937.

[9] N. Mooraki, Y. Batmany, S. J. Zoriehzahra, and S. Kakoolaki, "Evaluating the effect of using turmeric (Curcuma longa) on growth performance and hematological parameters of the ornamental fish, green terror (Andinocara rivulatus)," *Int. J. Aquat. Res. Environ. Stud.*, vol. 1, no. 1, pp. 49–59, 2021, doi: 10.61186/injoere.1.1.49.

[10] M. Radwan *et al.*, "Elucidating the effect of dietary neem (Azadirachta indica) on growth performance, haemato-biochemical, immunonological response, and anti-pathogenic capacity of Nile tilapia juveniles.," *Vet. Res. Commun.*,

vol. 48, no. 6, pp. 3621–3638, Dec. 2024, doi: 10.1007/s11259-024-10497-8.
[11] M. Khuanekkaphan, C. Noysang, and W. Khobjai, "Anti-aging potential and phytochemicals of Centella asiatica, Nelumbo nucifera, and Hibiscus sabdariffa extracts.," *J. Adv. Pharm. Technol. Res.*, vol. 11, no. 4, pp. 174–178, 2020, doi: 10.4103/japtr.JAPTR_79_20.
[12] I. Da-Costa-Rocha, B. Bonnlaender, H. Sievers, I. Pischel, and M. Heinrich, "Hibiscus sabdariffa L. - a phytochemical and pharmacological review.," *Food Chem.*, vol. 165, pp. 424–443, Dec. 2014, doi: 10.1016/j.foodchem.2014.05.002.
[13] L. G. Maciel *et al.*, "Hibiscus sabdariffa anthocyanins-rich extract: chemical stability, in vitro antioxidant and antiproliferative activities.," *Food Chem. Toxicol.*, vol. 113, pp. 187–197, Mar. 2018, doi: 10.1016/j.fct.2018.01.053.
[14] A. Escobar-Ortiz, E. Castaño-Tostado, N. E. Rocha-Guzmán, J. A. Gallegos-Infante, and R. Reynoso-Camacho, "Anthocyanins extraction from Hibiscus sabdariffa and identification of phenolic compounds associated with their stability.," *J. Sci. Food Agric.*, vol. 101, no. 1, pp. 110–119, Jan. 2021, doi: 10.1002/jsfa.10620.
[15] W. Huaysrichan, P. Prachaney, B. Kongyingyoes, U. Kukongviriyapan, A. Itharat, and P. Pannangpetch, "Hibiscus sabdariffa linn. Calyx extraction and gallic acid improving cardiac diastolic dysfunction in high fat diet-STZ-induced type 2 diabetic rats," *Asia-Pacific J. Sci. Technol.*, vol. 22, no. 2, pp. 1–9, 2017.
[16] V. Pérez-Escalante, G. Aguirre-Guzmán, P. E. Vanegas-Espinoza, and A. A. Del Villar-Martínez, "Effect of anthocyanin's extract from flour of roselle calyx (Hibiscus sabdariffa) on growth and pigmentation of goldfish (Carassius auratus)," *Thai J. Vet. Med.*, vol. 42, no. 1, pp. 107–111, 2012, doi: 10.56808/2985-1130.2354.
[17] A. Islam, T. Jamini, and A. Yeasmin, "Roselle: a functional food with high nutritional and medicinal values," *Fundam. Appl. Agric.*, vol. 1, no. 2, p. 44, 2016, doi: 10.5455/faa.302644242.
[18] V. V. Trichet, E. Santigosa, E. Cochin, and J. Gabaudan, "The Effect of Vitamin C on Fish Health," in *Dietary Nutrients, Additives, and Fish Health*, Wiley, 2015, pp. 151–171. doi: 10.1002/9781119005568.ch7.
[19] P. Houghton and A. Raman, *Laboratory Handbook for the Fractionation of Natural Extracts*. Springer US, 2012.
[20] R. Mattioli, A. Francioso, L. Mosca, and P. Silva, "Anthocyanins: a comprehensive review of their chemical properties and health effects on cardiovascular and neurodegenerative diseases," *Molecules*, vol. 25, no. 17, Aug. 2020, doi: 10.3390/molecules25173809.
[21] K. P. Besen, E. W. H. Melim, L. da Cunha, E. D. Favaretto, M. Moreira, and T. E. H. P. Fabregat, "Lutein as a natural carotenoid source: Effect on growth, survival and skin pigmentation of goldfish juveniles (Carassius auratus)," *Aquac. Res.*, vol. 50, no. 8, pp. 2200–2206, Aug. 2019, doi: 10.1111/are.14101.
[22] T. T. T. Hien *et al.*, "Dietary effects of carotenoid on growth performance and pigmentation in bighead catfish (Clarias macrocephalus Günther, 1864)," *Fishes*, vol. 7, no. 1, 2022, doi: 10.3390/fishes7010037.
[23] L. Sholichah, P. Priyanti, N. Meilisza, R. Fitriyah, S. Murniasih, and R. Hirnawati, "Pengaruh penambahan tepung bunga rosela pada pakan untuk pertumbuhan dan sintasan ikan koi (Cyprinus carpio L.) [The effect of adding roselle flower flour to feed on the growth and survival of koi fish (Cyprinus carpio L.)]," *Media Akuakultur*, vol. 18, no. 1, p. 31, Sep. 2023, doi: 10.15578/ma.18.1.2023.31-38.
[24] A. . Khiabani, A. Keramat, and R. Tahergorbi, "Review: Use of Highly unsaturated fatty acid (HUFA) in ornamental fish feeds," *J. Surv. Fish. Sci.*, vol. 6, no. 1, Jul. 2019, doi: 10.18331/SFS2019.6.1.7.
[25] Y. Velasco-Santamaría and W. Corredor-Santamaría, "Nutritional requirements of freshwater ornamental fish: a review," *Rev. MVZ Córdoba*, vol. 16, no. 2, pp. 2458–2469, May 2011, doi: 10.21897/rmvz.283.
[26] Z. Sankian, S. Khosravi, Y.-O. Kim, and S.-M. Lee, "Effect of dietary protein and lipid level on growth, feed utilization, and muscle composition in golden mandarin fish Siniperca scherzeri," *Fish. Aquat. Sci.*, vol. 20, no. 1, p. 7, 2017, doi: 10.1186/s41240-017-0053-0.
[27] K.-D. Kim, S. G. Lim, Y. J. Kang, K.-W. Kim, and M. H. Son, "Effects of dietary protein and lipid levels on growth and body composition of juvenile far eastern catfishSilurus asotus.," *Asian-Australasian J. Anim. Sci.*, vol. 25, no. 3, pp. 369–374, Mar. 2012, doi: 10.5713/ajas.2011.11089.
[28] E. M. Sihombing, L. P. Sitanggang, and N. Halawa, "Pengaruh perbandingan kuning telur dan tepung kedelai pada pasta terhadap pertumbuhan larva ikan koi (Cyprinus carpio) [The effect of the ratio of egg yolk and soybean flour in pasta on the growth of koi fish larvae (Cyprinus carpio)]," *J. Penelit. Terap. Perikan. dan Kelaut.*, pp. 46–53, 2020, doi: 10.300491/tapian%20nauli.v2i2.53.
[29] U. M. Papilon and M. Efendi, *Ikan Koi [Koi fish]*. Jakarta: Penebar Swadaya, 2017.
[30] R. C. Mukti, M. Amin, and M. I. Sari, "Kandungan nutrisi dan aktivitas antioksidan daun nipah (Nypa Fruticans Wurmb) sebagai bahan pakan ikan [Nutrition content and antioxidant activities of nipah leaves (Nypa Fruticans Wurmb) as aquafeed," *Media Akuatika J. Ilm. Jur. Budid. Perair.*, vol. 5, no. 3, pp. 106–114, 2020.
[31] M. Musdalifah, H. Syam, and R. Fadilah, "Pembuatan pakan ikan berbahan baku tepung kepala udang dan daun tarum (Indigofera SP) untuk peningkatan nilai nutrisi pakan ikan [Making fish feed from shrimp head flour and tarum leaves (Indigofera SP) to increase the nutritional value of fish feed]," *J. Pendidik. Teknol. Pertan.*, vol. 5, no. 2, p. 82, Feb. 2020, doi: 10.26858/jptp.v5i2.9936.
[32] S. W. Ningsi, A. Kurnia, and I. Nur, "Pengaruh penambahan tepung kulit buah manggis (Garcinia mangostana L.) terhadap tingkat kecerahan warna ikan nemo [The effect of addition of mangosteen (Garcinia mangostana L.) peel flour to the brightness level of clown fish (Amphiprion percula)]," *Media Akuatika*, vol. 3, no. 1, pp. 564–571, 2018.
[33] R. M. Cheriyan and B. Karpagam, "Effect of Hibiscus rosa-sinensis and Cassia auriculata on immune response of Cirrhinus mrigala infected with Aeromonas hydrophila," *Int. J. Creat. Res. Thoughts*, vol. 9, no. 4, pp. 2404–2411, 2021.
[34] S. Herlina, "Efektivitas ekstrak daun mengkudu (Morinda citrifolia) untuk meningkatkan respon imun non spesifik dan kelangsungan hidup ikan mas (Cyprinus carpio)," *J. Ilmu Hewani Trop.*, vol. 6, no. 1, pp. 1–4, 2017.
[35] T. P. Ijinu *et al.*, "Anthocyanins as immunomodulatory dietary supplements: a nutraceutical perspective and micro-/nano-strategies for enhanced bioavailability," *Nutrients*, vol. 15, no. 19, Sep. 2023, doi: 10.3390/nu15194152.
[36] E. Cenk *et al.*, "Immunomodulatory properties of blackberry anthocyanins in THP-1 derived macrophages," *Int. J. Mol.*

Sci., vol. 22, no. 19, p. 10483, Sep. 2021, doi: 10.3390/ijms221910483.
[37] J. Zhen *et al.*, "Phytochemistry, antioxidant capacity, total phenolic content and anti-inflammatory activity of Hibiscus sabdariffa leaves," *Food Chem.*, vol. 190, pp. 673–680, Jan. 2016, doi: 10.1016/j.foodchem.2015.06.006.
[38] W. Weerasingha, M. Chandrasiri, K. Hewawitharana, and J. Sampath, "Evaluation of anthocyanin extracted from Hibiscus rosa sinensis as a natural food colorant," *10th Annu. Sci. Res. Sess.*, pp. 17–20, 2021.
[39] H. N. Sköld, S. Aspengren, K. L. Cheney, and M. Wallin, "Fish Chromatophores—From Molecular Motors to Animal Behavior," 2016, pp. 171–219. doi: 10.1016/bs.ircmb.2015.09.005.
[40] A. P. Das, "Carotenoids and pigmentation in ornamental fish," *J. Aquac. Mar. Biol.*, vol. 4, no. 5, Oct. 2016, doi: 10.15406/jamb.2016.04.00093.
[41] C. C. C. R. de Carvalho and M. J. Caramujo, "Carotenoids in aquatic ecosystems and aquaculture: A colorful business with implications for human health," *Front. Mar. Sci.*, vol. 4, no. APR, 2017, doi: 10.3389/fmars.2017.00093.
[42] A. Dávalos, B. Bartolomé, and C. Gómez-Cordovés, "Antioxidant properties of commercial grape juices and vinegars," *Food Chem.*, vol. 93, no. 2, pp. 325–330, 2005, doi: 10.1016/j.foodchem.2004.09.030.
[43] S. Sukarman, R. Hirnawati, S. Subandiyah, N. Meilisza, and I. W. Subamia, "Penggunaan tepung bunga marigold dan tepung Haematococcus pluvialis sebagai sumber karotenoid pengganti astaxantin untuk meningkatkan kualitas warna ikan koi [The use of marigold flower flour and Haematococcus pluvialis flour as a source of carotenoids to," *J. Ris. Akuakultur*, vol. 9, no. 2, p. 237, Aug. 2014, doi: 10.15578/jra.9.2.2014.237-249.
[44] N. Fitriana, I. W. Subamia, and S. Wahyudi, "Pertumbuhan dan performansi warna ikan mas koki (Carassius sp.) melalui pengayaan pakan dengan kepala udang [Growth and color performance of goldfish (Carassius sp.) through feed enrichment with shrimp heads]," *Al-Kauniyah J. Biol.*, vol. 6, no. 1, pp. 1–12, 2013, doi: 10.15408/al-kauniyah.v6i1.2825.
[45] T. Yaeni, Suminto, and T. Yuniarti, "Pemanfaatan ekstrak ubi jalar (Ipomoea batatas var Ayumurasaki) dalam pakan untuk performa warna tubuh, pertubuhan dan kelulushidupan ikan rainbow (Melanotaenia praecox) [Utilization of sweet potato extract (Ipomoea batatas var Ayumurasaki) in feed for bo," *J. Aquac. Manag. Technol.*, vol. 6, no. 3, pp. 293–302, 2017, doi: 10.32491/jii.vv19il.398.
[46] D. Darsiani *et al.*, "Effect of adding carrot flour (Daucus carota) to commercial feed on increasing the brightness of the body color of goldfish (Carassius auratus)," *J. Aquac. Sci.*, vol. 10, no. 1, pp. 48–55, 2025, doi: 10.20473/joas.v10i1.68957.
[47] G. Koncara, N. B. P. Utomo, M. Setiawati, and M. Yamin, "Peningkatan kualitas warna ikan sumatra albino, Puntigrus tetrazona (Bleeker, 1855) dengan pakan buatan yang diperkaya tepung bayam merah (Amaranthus tricolor L.) [Improved quality of color sumatra barb, Puntigrus tetrazona (Bleeker, 1855) with artificial," *J. Iktiologi Indones.*, vol. 19, no. 1, pp. 53–64, 2019, doi: 10.32491/jii.v19i1.398.
[48] B. Yuangsoi, O. Jintasataporn, P. Tabthipwon, and C. Kamel, "Utilization of carotenoids in fancy carp (Cyprinus carpio): astaxanthin, lutein and β-carotene.," *World Appl. Sci. J.*, vol. 11, no. 5 PP-Faisalabad, pp. 590–598, 2010.