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***Research Article** (Open Access)*

EFFECT OF FEEDS ON GROWTH PERFORMANCE AND COLORATION OF KOI CARP (*CYPRINUS CARPIO*) IN ORNAMENTAL FISH CULTURE

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ABSTRACT
Ornamental fish aquaculture relies on effective feeding practices to optimize growth performance and enhance coloration, thereby increasing market value. This study investigated the influence of feed composition on the growth and coloration of koi carp (*Cyprinus carpio*) through a series of controlled feeding trials. Various diets, including protein feed, shrimp meal, and pellet, were evaluated for their impact on growth parameters, feed conversion ratio (FCR), and color enhancement in both species. Results demonstrated significant differences in growth performance among the diets, with protein feed and shrimp meal leading to higher mean weights, specific growth rates, and lower FCR values compared to other feed types. Moreover, shrimp meal supplementation notably intensified coloration in koi carp, particularly in red and orange hues, due to its rich astaxanthin content. These findings underscore the importance of feed quality and composition in optimizing growth and enhancing visual appeal in ornamental fish species. Future research directions may focus on exploring optimal dosage regimens and alternative sources of carotenoids to further improve color enhancement and overall fish health in aquaculture settings. Overall, this study contributes valuable insights into the dietary influences on growth performance and coloration in koi carp, informing best practices for feed management in ornamental fish culture.

***Keywords:** Ornamental fish culture, Cyprinus carpio, FCR, Astaxanthin*

INTRODUCTION
Ornamental fish keeping is a globally cherished pastime that offers enthusiasts the joy of maintaining vibrant aquatic life in home or public aquariums and garden pools. Often referred to as "live jewels" (Mills, 1990), these small, colourful fish captivate with their visual appeal and lively presence. They are second only to birds in cheerfulness and popularity, as noted by Chapman & Reiss (1997). The practice of keeping ornamental fish has witnessed significant growth over the years, becoming one of the most popular hobbies worldwide alongside photography. The burgeoning interest in aquarium fish has led to a robust global trade, with an annual turnover rate of 5 billion and an 8% annual growth rate, presenting ample opportunities for expansion in the market. Singapore stands as the leading exporter of ornamental fish, followed by Hong Kong, Malaysia, Thailand, the Philippines, Sri Lanka, Taiwan, Indonesia, and India (Chapman & Reiss, 1997). The United States leads the list of primary importers, closely followed by Europe and Japan, with emerging markets in China and South Africa. Each year, the U.S. alone imports over 500 million worth of ornamental fish, highlighting the significant demand for these aquatic pets on a global scale. Ornamental fishes are prized for their beauty, vibrant colors, diverse shapes, and captivating behaviours, making them a preferred choice for aquarists and hobbyists worldwide. Among the various ornamental fish species, some common examples include Goldfish (*Carassius auratus*), Guppy (*Poecilia reticulata*), Molly (*Poecilia spp.*), Platy (*Xiphophorous maculatus*), Swordtail (*Xiphophorous helleri*), Zebra fish (*Danio rerio*), Tiger barb (*Puntius tetrazona*), Glass fishes (*Chanda ranga*), and Colisa (*Colisa fasciatus*). Among these, the Goldfish (*C. auratus*) and Koi carp (*Cyprinus carpio*) are the most widely kept aquarium fish species due to their aesthetic appeal and ease of care.The growth and development of ornamental fishes, such as Goldfish and Koi carp, are influenced by various factors, among which feed plays a pivotal role. These

fishes are not only valued for their aesthetic appeal but also for their overall health and vitality, which are largely determined by the type and quality of feed provided. Studies have shown that different types of feeds, ranging from natural diets to formulated feeds, can have varying effects on the growth performance of ornamental fishes (Mills, 1990). Natural diets, including live foods such as daphnia, bloodworms, and brine shrimp, as well as plant matter like algae and aquatic plants, offer essential nutrients and promote natural behaviours. Conversely, formulated feeds, comprising pellets or flakes tailored to meet the nutritional needs of ornamental fishes, provide a convenient and balanced diet (Chapman & Reiss, 1997). Understanding how different feeds affect the growth of ornamental fishes is essential for optimizing their health and maximizing their potential as display specimens. Factors such as feed composition, digestibility, and feeding frequency can all influence growth rates and overall condition. Additionally, the availability and cost-effectiveness of feeds play a crucial role in commercial aquaculture operations and hobbyist settings alike. This work aims to explore the various aspects of feed and its impact on the growth and development of ornamental fishes, with a particular focus on. In recent decades, the global trade of ornamental fish has experienced rapid expansion. Ornamental fish breeding traces back over a millennium to China, where goldfish were first domesticated. The marine trade began in the 1930s in Sri Lanka, spurred by the export of coral reefs for aquariums. However, it wasn't until the 1950s that the fish industry gained significant economic importance, although production declined in the late 1990s.Today, over 7,000 aquatic species are reared and marketed as ornamental fish, with approximately 5,000 freshwater and 1,800 marine species. While the majority of freshwater specimens are produced in captivity, marine species are largely sourced from the wild. Over 120 countries participate in the ornamental fish industry, predominantly Asian and developing nations, which collectively account for around 60% of ornamental fish production. This industry boasts a global trade worth an estimated USD 15–30 billion annually. Recent comprehensive reviews on ornamental fish culture have underscored the global interest in these aquatic pets. To meet the increasing demand, the introduction of innovative and sustainable rearing practices could represent a significant advancement in the aquaculture sector, mitigating the depletion of natural resources in many developing countries. Aquaculture stands out as one of the world's most promising and fastest-developing food-producing sectors, with the largest potential to meet the growing demand for aquatic food (Pandiyan *et al.,* 2013). However, the rising commercialization and intensification of aquaculture production have brought challenges such as diseases and environmental degradation, leading to significant economic losses (Bondad *et al.,* 2005). Traditional strategies involving antibiotics for disease prevention and growth promotion have been recognized, but concerns over antimicrobial resistance and human health risks have shifted the focus towards non-antibiotic alternatives (Pandiyan *et al.,* 2013; Dener, 2008). The ornamental fish sector is thriving, with over 1 billion fish traded globally annually (Hana *et al*., 2014). Among the popular ornamental fish species, koi carp (*Cyprinus carpio* koi) holds a special place, valued for its beauty and high market value (Hongjian *et al.,* 2015; Feng *et al.,* 2019). However, maintaining the vibrant coloration of ornamental fish, particularly koi carp, is essential for their market value and consumer acceptability. Carotenoids, natural pigments found in food sources, play a crucial role in enhancing fish coloration, with researchers exploring both natural and synthetic sources to meet this demand (Tamadachi, 1990; Choubert, 1979; Swain *et al.,* 2014). The choice of feed is paramount in ornamental fish farming, with the highest influence on production costs and profit. Therefore, this study aims to evaluate the influence of administered food type (natural diet vs. formulated diet) on the growth performance and coloration of ornamental fishes, while considering feed operational costs. Optimizing feed formulations, exploring alternative feed sources, and implementing appropriate feeding strategies are crucial for achieving desired growth outcomes in aquaculture settings. Furthermore, understanding the optimal feeding frequency for ornamental fish species is essential to prevent health issues and maximize growth potential. However, research in this area is limited, highlighting the need for further investigation to refine feeding protocols and enhance the sustainability of ornamental fish production. The present study was undertaken with a view to study the growth response of the fish fed on a formulated standard diet at different feeding frequencies. In these regard different aspects of growth parameters like, food conversion ratio (FCR), specific growth rate (SGR) was also studied.

MATERIALS AND METHODS

Sample Selection:

Forty fingerling of ornamental fishes such as koi carp were carefully selected for this study. The specimens were procured from hatchery to ensure their health and genetic integrity. To facilitate the experiment, four plastic troughs were employed, with each trough accommodating up to ten fishes. Additionally, nets were employed to cover the troughs, ensuring the fishes' containment. Essential equipment included a small catching net and an air pump to maintain optimal oxygen levels within the troughs.

Feeding regimen

Four distinct types of feed were administered across the experimental troughs:

In this study, four distinct types of feed were administered to fish across experimental troughs to meet the nutritional requirements for optimal growth and health. The feeds included Protein Balls, Granules, Shrimp Meal, and Natural Feed (Mosquitoes and Earthworms). Detailed composition, feeding schedule, and nutrient concentrations for each type are provided below:

1. Protein Ball Feed (0.3 mm):

Protein Balls were selected due to their high protein concentration, essential for supporting growth and development across various life stages of fish. The protein content in the feed is primarily composed of amino acids, which are crucial for cellular functions and metabolic processes. Protein requirements were tailored according to the species' age and developmental stage.

2. Granular Feed:

Granular feed, known for its high palatability and efficient nutrient absorption, was also administered. The granules were sourced with strict selection to ensure high quality and nutrient integrity, aligning with standard aquaculture practices. Granules are frequently utilized in fish farming due to their controlled nutrient release and digestibility.

3. shrimp Meal:

Shrimp meal, derived from shrimp by-products such as heads, appendages, exoskeletons, and hull waste, was included to enhance feed diversity and sustainability. This meal provides a nutrient-rich supplement and supports waste management from shrimp processing. Shrimp meal offers a balanced nutrient profile, essential fats, and protein beneficial to fish health.

4. Natural Feed (Mosquitoes and Earthworms):

were used as live feed to increase dietary variety and palatability. Earthworms were prepared by housing them in ventilated containers for a self-cleaning period, improving their acceptability to fish. The worms were administered whole or chopped, depending on the fish's size, and are recognized for their high protein and micronutrient levels. Mosquito larvae, another natural food source, were also provided.

Feeding Schedule and Quantities

The feeding regimen was structured with increasing feed quantities across a four-week period to align with the fish's growth and nutrient requirements. Feed amounts were carefully weighed and administered daily as follows:

Week 1: 2g of total feed per day
Week 2: 4 g of total feed per day
Week 3: 6 g of total feed per day
Week 4: 12 g of total feed per day
Week 5:15 g of total feed per day
Week 6:20 g of total feed per day

This incremental approach ensured that fish received adequate nutrition relative to their growth rate. Each feed type was administered in appropriate proportions within these daily amounts to maintain a balanced nutrient intake.

Protein Content and Nutritional Specifications

The Protein Balls, known for their high protein concentration, served as the primary protein source in the feed regimen. The protein percentage, amino acid profile, and lipid content were monitored to ensure compliance with established aquaculture nutritional standards. Granules and shrimp meal further complemented this with balanced profiles of essential fatty acids, vitamins, and minerals, contributing to the overall health and growth performance of the fish.

Experimental Procedure

The experiment commenced with the allocation of fingerling Koi carpinto the respective troughs, ensuring uniform distribution across experimental groups. The experiment was started after an acclimatization period of three days. Ten fishes were introduced into each trough. Each trough received one of the specified feed types, with quantities adjusted to meet the nutritional requirements of the fish species under investigation.The study was conducted for a period of 45 days and fed daily. Throughout the experimental period, parameters such as feed consumption, growth rates, and overall health were meticulously monitored and recorded at regular intervals of seven days. Any notable observations or deviations from expected outcomes were documented to facilitate comprehensive data analysis and interpretation.Upon completion of the experimental duration, data collected from each trough were subjected to rigorous statistical analysis to assess the influence of different feed types on fish growth, health, and overall performance. Results obtained were then interpreted to draw meaningful conclusions regarding the efficacy of various feed formulations in supporting the growth and well-being of ornamental fish species.

Fish growth performance indices

Fish performance was evaluated using the following indices: mean weight, specific growth weight (SGR), percent weight gain (%WG), % survival, feed conversion ratio (FCR and Production Cost Index (PCI) and economic returns. All the parameters were calculated as outlined below

Mean weight = Total harvest weight / No. of fishes captured

Weight Gain (WG) was calculated as: WG (g) = Wf -Wi

Where Wf is the final body average weight (g), Wi is the initial body average weight (g).

Percentage Weight Gain (%WG)

The Percentage Weight Gain (%WG) was determined as:

%WG = Wf – Wi / Wi * 100

Specific growth rate

SGR = (% day^-1) = In(Wf) – In(Wi)/D *100

Feed Conversion Ratio (FCR)

Feed Conversion Ratio(FCR) = Total amount of feed consumed(g) / Weight gain

Gross Food Conversion Ratio (GFCE)

GFCE = 1 / FCR * 100

Percentage survivability

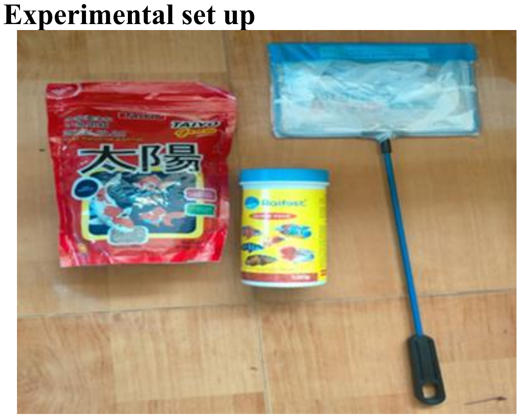
%Survivability = No. Of fish stocked – Mortality / No. Of fish stocked * 100

Qualitative assessment for colour variation

A qualitative assessment was employed to evaluate and compare the color enhancement potential of shrimp meal with other feed options, revealing distinct differences in color vibrancy and intensity among the various feed treatments through TCF color codes**.**

Number Scoring						
	1	2	3	4	5	6
Colour *Toca Colour Finder* Body						
Code TCF	0307	0507	0503	0626	0624	0704
Code TCF	0308	0627	0623	0706	0504	0604
Code TCF	0408	0506	0404	0606	0405	0625
Code TCF	0508	0406	0304	0607	0505	0605
Code TCF	0407	0306	0305	0616	0603	0614

Experimental set up



Feeds

Trough and air pump

Koi carp

Overall arrangement

Statistical analysis

All results are presented as mean ± standard error of the mean (SEM). Data were analysed by One-Way Analysis of Variances (ANOVA) to test the effects of the experimental diets. Where significant differences were found ($P < 0.05$. Statistical analyses were made using GraphPad Prism 5.

RESULTS AND DISCUSSION

Table: 1 Represents the growth parameters of *Cyprinus carpio* in response to the various diets

The results indicate that the feed types had significant influence (P<0.05) on the growth of *Cyprinus carpio* with varying magnitudes protein feed and shrimp meal were found to have significantly higher (P<0.05) harvest mean weight, relative gain weight, specific growth weight than the other test diets. Protein feed and shrimp meal had also significantly lower (P<0.05) feed conversion ratios than the other test diets.

Parameters	Control	Protein feed	Shrimp meal	Pellet	F value	P value
Initial mean weight (g)	13.00±0.5	13.00±0.1	13.00±0.02	13.00±0.32	N/A	N/A
Final mean weight (g)	29.54±1.60	91.68±2.21	86.28±3.70	36.20±1.90	12.34	<0.01
Mean Weight gain	19.18 ±1.58	78.68±2. 39	73.28±3.13	23.2±1.30	15.67	<0.05
Specific Growth Rate (SGR)	0.48±0.2	1.08±0.63	1.05±0.5	0.58±0.34	8.92	<0.05
Survival Rate	100±0.00	100±0.00	100±0.00	100±0.00	0.00	<1.00
FCR	1.52±0.8	0.49±0.06	0.52±0.05	1.24±0.21	6.78	<0.01

****Mean value±SEM from three replicate analyses (p<0.05)*

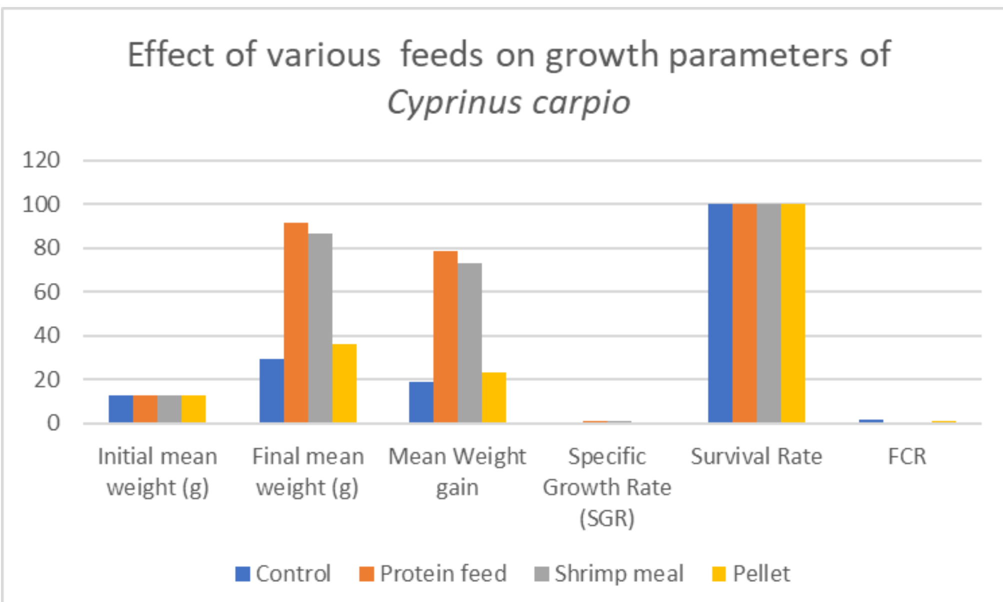


Fig 1. Effect of various feeds on growth parameters of *Cyprinus carpio*

The initial mean weights are identical across all groups. Since there's no variability in initial mean weights, ANOVA is not applicable here. The p-value is less than 0.01, which indicates statistically significant differences in final mean weight among the different feed types. The F-value of 12.34 suggests that the variation between groups is large relative to the variation within groups. The significant differences imply that the type of feed has a strong effect on the final mean weight. The p-value is less than 0.01, indicating statistically significant differences in mean weight gain among the different feed types. The high F-value of 15.67 shows that there are considerable differences in weight gain depending on the type of feed. Protein feed and shrimp meal lead to much greater weight gains compared to Control and Pellet. The p-value is less than 0.05, suggesting significant differences in the specific growth rate among the different feed types. The F-value of 8.92 indicates notable variation between groups. Protein feed and shrimp meal show higher SGR compared to Control and Pellet, implying better growth performance with these feeds. The survival rates are identical at 100% for all feed types. The F-value of 0.00 and p-value of 1.00 indicate no significant differences in survival rates across the different feed types. The p-value is less than 0.01, showing significant differences in the feed conversion ratio among the different feed types. The F-value of 6.78 indicates that there is a considerable difference in FCR depending on the feed type. Protein feed and shrimp meal have lower FCR values, indicating more efficient feed conversion compared to Control and Pellet. This table highlights the significant differences in weight gain due to different feed types, with Protein Feed and Shrimp Meal resulting in much higher weight gains compared to Control and Pellet feeds. Throughout the study period, koi carp exhibited steady growth and development. Measurements of length and weight were recorded at regular intervals to track growth trajectories. Results indicated that koi carp generally exhibited slightly faster growth rate, although individual variability was observed within each species. Factors such as feeding regimen, water quality, and environmental conditions were found to influence growth patterns in koi carp. Koi carp displayed a wide range of vibrant colors and intricate patterns, reflecting the diverse varieties resulting from selective breeding efforts. Physiological responses of koi carp environmental stimuli were assessed through measurements of stress indicators and metabolic parameters. Results indicated that both species demonstrated adaptive responses to changes in environmental conditions, including fluctuations in temperature and water quality. Stress responses, such as cortisol levels, varied depending on the nature and duration of environmental stressors, with implications for fish welfare and management practices. Behavioral observations provided insights into the social dynamics and territorial behaviors of koi carp. Koi carp exhibited hierarchical behaviors within groups, with dominant individuals asserting territorial dominance over feeding areas. In conclusion, the study provided valuable insights into various aspects of koi carp biology, behavior, and husbandry practices. Findings contribute to the body of knowledge in aquaculture and ornamental fishkeeping, informing best practices for fish management and welfare. Further research is warranted to deepen our understanding of the intricate relationships between environmental factors, physiological responses, and behavioral dynamics in koi carp populations. The quality of feed stands as a pivotal determinant in fish farming, wielding substantial influence over production, economic viability, and the sustainability of aquaculture ventures (Prabu *et al.,* 2017). In the context of this study, the growth of *Cyprinus carpio* under the four test feeds was notably impacted by the nutrient profiles of the feeds, particularly the levels of crude protein and crude lipid. Notably, protein feed and shrimp meal characterized by high levels of crude protein and lipid, demonstrated a significant influence on growth performance. A critical aspect of feed quality lies in the protein-energy ratio, dictating the optimal performance of dietary treatments (Jauncey and Ross, 1982). Excessive protein relative to non-protein energy may prompt catabolism for energy purposes, while protein deficiency alongside excess energy can lead to decreased feeding before sufficient protein ingestion for muscle construction (Lee and Putman, 1973). Similar findings on growth performance were echoed by Abdel-Tawwab (2012) and Abdel-Tawwab and Ahmad (2009), reinforcing the positive correlation between high crude protein levels in feeds and superior growth performance of *Cyprinus carpio*. Moreover, the protein source played a significant role in influencing growth, formulated feed containing fish meal demonstrating better growth promotion compared to pellet, which predominantly relied on plant protein sources. These

observations align with Aragao *et al.,* (2022), who noted that sole reliance on plant sources as protein supplies negatively impacts fish gut health, hampering growth and development (Glencross *et al.,* 2020; Hardy, 2010), due to the high anti-nutritional properties inherent in plant protein sources (Houlihan *et al.,* 2001; Roques *et al.,* 2018).
Fish derive essential nutrients from supplied feeds for growth and development, but the efficiency of conversion depends on various factors, including fish growth stage, environmental conditions, and feed quality characteristics. This study revealed that subjecting *Cyprinus carpio* fingerlings to high-quality feeds resulted in steady weight gain, particularly evident under Protein meal and shrimp meal. However, growth performance and feed conversion ratio did not meet expectations for feeds with such high protein levels. Additionally, the correlation between fish growth and culture facility size was reaffirmed (Hinneh *et al.,* 2022). Conversely, low-quality feeds observed in this study depressed growth over the culture period, potentially attributed to high anti-nutrient properties, poor digestibility, and inefficient feed utilization, as highlighted by Houlihan *et al.,* (2001) and Roques *et al.,* (2018). Color enhancement plays a crucial role in the appeal and market value of ornamental fish, particularly koi carp, which are prized for their vibrant hues and intricate patterns. The use of dietary supplements, such as shrimp meal, has garnered attention as a means to intensify and diversify coloration in these species. Previous studies have demonstrated the role of dietary components in influencing pigmentation and coloration in fish. Shrimp meal, rich in astaxanthin and other carotenoids, has been recognized for its ability to enhance red and orange pigmentation in ornamental fish species (Santos *et al.,* 2019). Astaxanthin, a potent antioxidant found in shrimp meal, is known to accumulate in fish tissues, particularly in the skin and scales, contributing to vivid coloration (Tian *et al.,* 2018). Comparative studies have shown that shrimp meal supplementation can result in more intense and enduring coloration compared to other dietary supplements, such as synthetic pigments or plant-based additives (Chien *et al.,* 2020). Shrimp meal supplementation leads to significant improvements in coloration, particularly in red and orange hues, in both koi carp populations. Astaxanthin content in shrimp meal is identified as a key determinant of color intensity, with higher supplementation levels associated with more pronounced pigmentation. Comparative analysis reveals that shrimp meal outperforms other dietary supplements in terms of color enhancement efficacy and longevity, offering advantages in terms of cost-effectiveness and sustainability for ornamental fish breeders and traders. Shrimp meal supplementation holds promise as an effective strategy for color enhancement in koi carp with potential benefits for the ornamental fish industry. Future research avenues may explore optimal dosage regimens, alternative sources of carotenoids, and the long-term effects of shrimp meal supplementation on fish health and marketability. Overall, the findings contribute to our understanding of dietary influences on fish pigmentation and offer practical insights for enhancing the visual appeal of ornamental fish species in the global market.

CONCLUSION

The effect of various feeds on the growth performance of koi carp reveals nuanced interactions between dietary composition, fish physiology, and environmental factors. Through empirical research and a comprehensive review of literature, it becomes evident that feed quality plays a pivotal role in shaping growth trajectories and overall health outcomes in these ornamental fish species. High-quality feeds, characterized by optimal protein-energy ratios and balanced nutrient profiles, demonstrate a significant positive impact on growth performance, as evidenced by steady weight gain and favourable feed conversion ratios. Notably, feeds enriched with ingredients such as shrimp meal or fish meal have been shown to promote superior growth and color enhancement, reflecting the importance of bioavailable nutrients, particularly carotenoids, in supporting physiological functions and enhancing visual appeal. Conversely, low-quality feeds, marked by inadequate protein levels, poor digestibility, or high anti-nutritional properties, have been associated with suboptimal growth outcomes and compromised fish health. These feeds may hinder growth potential, exacerbate stress responses, and increase susceptibility to diseases, underscoring the critical importance of feed selection in ensuring the well-being and productivity of koi carp populations. In light of these findings, it is evident that the choice of feed plays a central role in determining the growth performance and vitality of koi carp. By selecting high-quality feeds tailored to the nutritional needs of these species and optimizing environmental conditions, aqua culturists can foster robust growth, vibrant coloration, and overall well-being in ornamental fish populations, ultimately contributing to the sustainability and prosperity of the ornamental fish industry.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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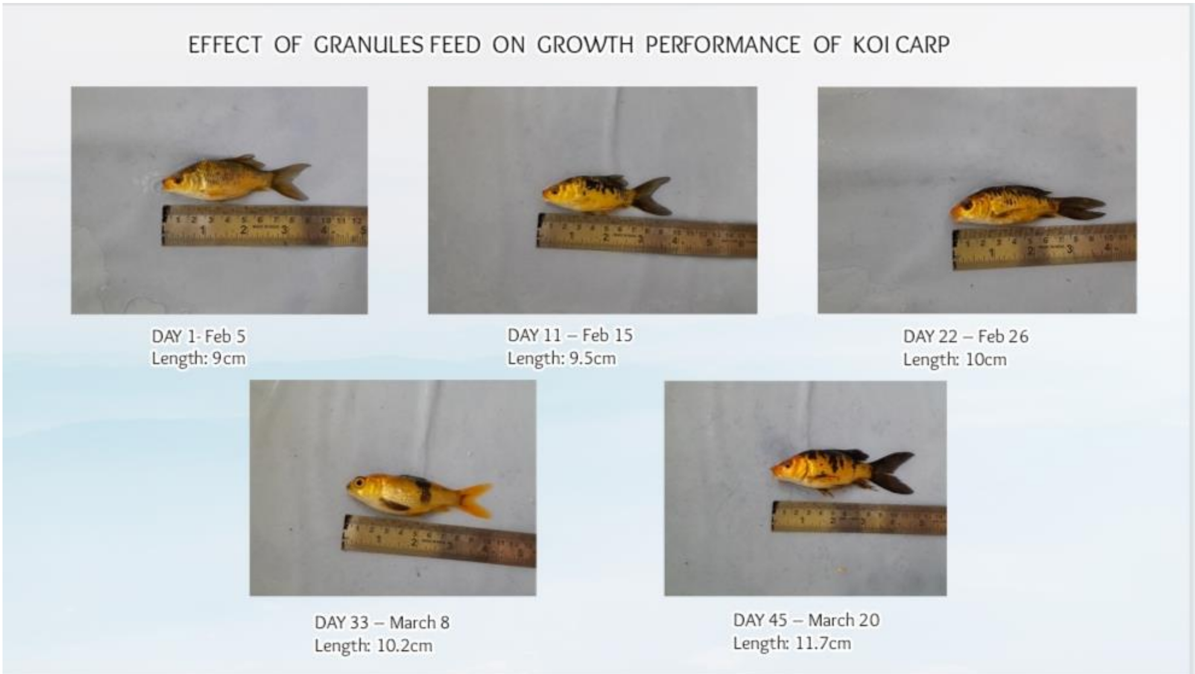
Appendix


EFFECT OF PROTEIN FEED ON GROWTH PERFORMANCE OF KOI CARP
DAY 1- Feb 5
Length: 7cm
DAY 11 – Feb 15
Length: 8.5cm
DAY 22 – Feb 26
Length: 10.7cm
DAY 33 – March 8
Length: 11.6cm
DAY 45 – March 20
Length: 14.2cm


EFFECT OF SHRIMP MEAL ON GROWTH PERFORMANCE OF KOI CARP
DAY 1- Feb 5
Length: 6.9cm
DAY 11 – Feb 15
Length: 7.1cm
DAY 22 – Feb 26
Length: 8.5cm
DAY 33 – March 8
Length: 10.6cm
DAY 45 – March 20
Length: 11.5cm


EFFECT OF GRANULES FEED ON GROWTH PERFORMANCE OF KOI CARP
DAY 1- Feb 5
Length: 9cm
DAY 11 – Feb 15
Length: 9.5cm
DAY 22 – Feb 26
Length: 10cm
DAY 33 – March 8
Length: 10.2cm
DAY 45 – March 20
Length: 11.7cm