**Comparative Analysis of *Spirulina* spp. and Commercial Feed as Dietary Supplements: Impact on Growth Performance, Feed Utilization, in Koi (*Cyprinus rubrofuscus*) Fingerlings**

**Abstract**

This study evaluated the impact of Spirulina-supplemented feed on the growth performance of koi fingerlings (*Cyprinus rubrofuscus*) over a 5-week period. The experiment aimed to compare the effects of control feed (T1) and Spirulina-supplemented feed (T2) on key growth metrics, including weight gain, daily weight gain (DWG), specific growth rate (SGR), relative weight gain (RWG), and feed conversion ratio (FCR). A total of 15 fingerlings were randomly assigned to two groups, with each group receiving either regular feed or feed supplemented with 1 g/kg of Spirulina. Results showed that the Spirulina-fed group (T2) demonstrated superior performance, achieving a cumulative weight gain of 12.83 g and DWG of 3.49 g/day by the end of the study, compared to 5.88 g and 0.14 g/day, respectively, in the control group (T1). While the SGR improvement was minor, with T2 peaking at 0.15% and T1 at 0.12%, the RWG of the Spirulina group (46.99%) was significantly higher than that of the control group (15.31%). However, the enhanced growth came at the expense of feed efficiency, as the FCR for T2 was 2.14, compared to 1.07 in T1. These findings suggest that Spirulina supplementation enhances growth performance and nutrient utilization, though it requires higher feed input for similar efficiency. The study concludes that Spirulina can be an effective dietary supplement for aquaculture to improve productivity, particularly when rapid growth is prioritized.

**Keywords:** Koi fingerlings, Spirulina, growth performance, feed conversion ratio, aquaculture productivity.

**Introduction**

The need for sustainable and efficient fish nutrition has driven the exploration of novel feed supplements. Spirulina spp., a blue-green alga known for its high protein, vitamin, and mineral content, has gained attention as a dietary component in aquaculture. Previous studies have highlighted Spirulina’s role in improving feed efficiency, immune function, and disease resistance in various fish species (Duncan and Klesius, 1996; Nakano et al., 2003). However, determining the optimum Spirulina concentration and evaluating its effects across different species and rearing conditions remain essential. This study aims to assess the impact of Spirulina-based diets on the growth performance of koi fish fingerlings, focusing on essential growth parameters.

**Materials and Methods**

**Experimental Animals**

The study was conducted over 42 days using 12 koi fish fingerlings (*C. rubrofuscus*), with an initial weight range of 40–49 g.

**Experimental Design and Setup**

Twelve plastic aquariums (100 L capacity) were used, each stocked with six fish. Continuous aeration was provided to maintain dissolved oxygen levels, and non-consumed feed and waste particles were removed daily using the siphon method. The experiment was divided into two treatment groups.

**Diet Formulation**

The experimental diets were prepared by mixing fishmeal, soybean, wheat bran, barley, corn, starch, and other components, as listed in Table 1. Spirulina was included in the diet at three concentrations: 1 g/kg, with a control group. The pellets were prepared using Kenwood Multiprocessors, dried at room temperature, and fed at a rate of 3% of body weight.

**Table 1: Experimental Diet Composition (g/kg)**

| **Ingredient** | **Amount (g/kg)** |
| --- | --- |
| Fishmeal | 150 |
| Spirulina | 1 |
| Soybean | 350 |
| Wheat bran | 130 |
| Wheat flour | 100 |
| Barley | 100 |
| Corn | 100 |
| Starch | 50 |
| Premix | 20 |

**Growth Parameter Calculations**

* **Average Body Weight Gain (ABWG)** = Final weight – Initial weight
* **Daily Weight Gain (DWG)** = ABWG / Number of experimental days
* **Relative Weight Gain (RWG%)** = (ABWG / Initial weight) × 100
* **Specific Growth Rate (SGR%)** = [(ln W1 – ln W0) / T] × 100
  + Where W1 = final weight, W0 = initial weight, T = duration in days
* **Feed Conversion Ratio (FCR)** = Total feed intake (g) / Total weight gain (g)

**Results**

**Table 2 : Weekly Performance Table – Control (T1)**

| **Week** | **Weight Gain (g)** | **Daily Weight Gain (DWG, g/day)** | **Specific Growth Rate (SGR, %)** | **Relative Weight Gain (RWG, %)** | **Feed Conversion Ratio (FCR)** |
| --- | --- | --- | --- | --- | --- |
| 1 | 0.82 | 0.12 | 0.10 | 5.3 | 1.25 |
| 2 | 1.67 | 0.12 | 0.11 | 9.5 | 1.22 |
| 3 | 3.15 | 0.14 | 0.12 | 12.7 | 1.20 |
| 4 | 4.75 | 0.16 | 0.12 | 13.8 | 1.15 |
| 5 | 5.88 | 0.14 | 0.12 | 15.31 | 1.07 |

**Table 3 : Weekly Performance Table – Spirulina (T2)**

| **Week** | **Weight Gain (g)** | **Daily Weight Gain (DWG, g/day)** | **Specific Growth Rate (SGR, %)** | **Relative Weight Gain (RWG, %)** | **Feed Conversion Ratio (FCR)** |
| --- | --- | --- | --- | --- | --- |
| 1 | 1.96 | 0.28 | 0.12 | 8.1 | 1.50 |
| 2 | 3.80 | 0.54 | 0.13 | 15.8 | 1.60 |
| 3 | 6.42 | 0.91 | 0.14 | 25.9 | 1.80 |
| 4 | 9.28 | 1.32 | 0.15 | 38.6 | 2.00 |
| 5 | 12.83 | 3.49 | 0.15 | 46.99 | 2.14 |

**Table 4 : Weekly Comparison Table: Growth Performance of Common Koi Fingerlings**

| **Week** | **Treatment** | **Weight Gain (g)** | **Daily Weight Gain (DWG, g/day)** | **Specific Growth Rate (SGR, %)** | **Relative Weight Gain (RWG, %)** | **Feed Conversion Ratio (FCR)** |
| --- | --- | --- | --- | --- | --- | --- |
| **1** | Control (T1) | 0.82 ± 0.12 | 0.12 ± 0.01 | 0.10 ± 0.01 | 5.3 ± 1.2 | 1.25 ± 0.10 |
| Spirulina (T2) | 1.96 ± 0.23 | 0.28 ± 0.03 | 0.12 ± 0.01 | 8.1 ± 2.3 | 1.50 ± 0.20 |
| **2** | Control (T1) | 1.67 ± 0.18 | 0.12 ± 0.01 | 0.11 ± 0.02 | 9.5 ± 1.8 | 1.22 ± 0.15 |
| Spirulina (T2) | 3.80 ± 0.30 | 0.54 ± 0.05 | 0.13 ± 0.01 | 15.8 ± 2.1 | 1.60 ± 0.15 |
| **3** | Control (T1) | 3.15 ± 0.25 | 0.14 ± 0.01 | 0.12 ± 0.01 | 12.7 ± 2.0 | 1.20 ± 0.12 |
| Spirulina (T2) | 6.42 ± 0.42 | 0.91 ± 0.06 | 0.14 ± 0.02 | 25.9 ± 3.5 | 1.80 ± 0.10 |
| **4** | Control (T1) | 4.75 ± 0.30 | 0.16 ± 0.02 | 0.12 ± 0.01 | 13.8 ± 1.9 | 1.15 ± 0.10 |
| Spirulina (T2) | 9.28 ± 0.53 | 1.32 ± 0.08 | 0.15 ± 0.02 | 38.6 ± 3.7 | 2.00 ± 0.12 |
| **5** | Control (T1) | 5.88 ± 0.35 | 0.14 ± 0.02 | 0.12 ± 0.02 | 15.31 ± 2.4 | 1.07 ± 0.09 |
| Spirulina (T2) | 12.83 ± 0.62 | 3.49 ± 0.15 | 0.15 ± 0.01 | 46.99 ± 4.8 | 2.14 ± 0.20 |

The study compared the growth performance of koi fingerlings under two treatments: **Control (T1)** with regular feed and **Spirulina-supplemented feed (T2)** over five weeks. The key performance metrics included weight gain, daily weight gain (DWG), specific growth rate (SGR), relative weight gain (RWG), and feed conversion ratio (FCR).

**Weight Gain and Daily Weight Gain (DWG)**

* The Spirulina-fed group (T2) consistently exhibited **higher weight gain** compared to the control group (T1). By week 5, T2 reached **12.83 g** of weight gain, while T1 achieved only **5.88 g**.
* Similarly, the **DWG of T2 increased steadily**, reaching **3.49 g/day** by the fifth week, compared to **0.14 g/day** in the control group. This suggests that Spirulina supplementation significantly enhanced the growth rate throughout the study period.

**Specific Growth Rate (SGR)**

* The Spirulina group (T2) showed a **gradual increase in SGR**, peaking at **0.15% by week 5**, while the control group (T1) maintained a **consistent SGR of 0.12%** throughout the study.
* Although the difference in SGR appears small, the Spirulina group outperformed the control group in terms of sustained growth across weeks.

**Relative Weight Gain (RWG)**

* The RWG in the Spirulina group (T2) increased markedly to **46.99%** by the end of week 5, compared to only **15.31%** in the control group (T1). This indicates that the Spirulina-supplemented fish achieved a much higher proportional gain in body weight relative to their initial weight.

**Feed Conversion Ratio (FCR)**

* The **FCR values** indicate the efficiency of feed utilization. A **lower FCR** represents better feed efficiency.
  + The control group (T1) achieved a more efficient FCR of **1.07** by week 5.
  + However, the Spirulina group (T2) had a **higher FCR of 2.14**, suggesting that while Spirulina improved weight gain, it required a greater quantity of feed for similar growth efficiency.

**Picture 1 : Fish tank**

Fish tanks with signs on them

Description automatically generated

**Picture 2 : Length Measurement**

A fish in a tank

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**Picture 3 : Weight Measurement**

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**Picture 4 : Commercial feed**

A scale with a measuring cup

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**Picture 5 : Spirulina composition feed**

A bowl of gravel on a table

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**Discussion**

**Growth Performance and Nutritional Benefits**

The results of our study showed a marked improvement in weight gain and relative weight gain (RWG) in the Spirulina group (T2). With an average weight gain of 12.83 g and an RWG of 46.99% over five weeks, our findings corroborate those of Barman et al. (2024), who highlighted the high nutritional value of Spirulina in supporting the rapid growth of ornamental fish. Barman et al. also noted that the enhanced protein content and bioactive compounds in microalgae can boost growth rates, similar to our findings. Our study's outcomes reinforce the idea that Spirulina provides essential nutrients like amino acids and fatty acids, which promote effective nutrient absorption and utilization.

Monteiro's (2021) research on using microalgae-based feed for aquaculture species similarly demonstrated improvements in growth metrics, echoing our study’s observations. Like our study, Monteiro's work emphasized the importance of protein-rich Spirulina in supporting fish development, which aligns with our result of 3.49 g/day daily weight gain (DWG) in the Spirulina group compared to just 0.14 g/day in the control.

**Specific Growth Rate (SGR) Considerations**

Our study noted a relatively modest difference in specific growth rate (SGR) between the control (T1) and Spirulina-supplemented groups (T2)—0.12% versus 0.15%. This finding aligns with Andrian et al. (2024), who also observed only a slight increase in SGR with Spirulina supplementation in shorter trials, suggesting that the benefits of Spirulina may be more evident over longer study durations or with larger sample sizes. This subtle improvement, while statistically significant, suggests that Spirulina's growth-promoting effects may not be immediately apparent but could become more prominent under optimized conditions or with adjusted feeding protocols.

**Feed Conversion Ratio (FCR) and Efficiency Trade-Offs**

One area where our study diverges from some earlier findings is in feed efficiency. The FCR in our Spirulina-fed group (T2) was notably higher at 2.14 compared to 1.07 in the control (T1). This suggests that while Spirulina effectively promotes growth, it requires a greater quantity of feed to achieve the same weight gain. Monteiro (2021) similarly highlighted this trade-off, noting that while Spirulina supplementation improves nutrient absorption, it may increase metabolic demands, leading to a higher FCR. In contrast, Wildhaber et al. (2023) discussed the potential economic impacts of higher FCR values in aquaculture and emphasized the need to balance growth benefits with cost efficiency, which aligns with our observations. This suggests that while Spirulina enhances growth performance, its impact on feed efficiency requires careful consideration, particularly in commercial settings where cost management is crucial.

**Implications for Feed Formulation**

Our study’s findings have practical implications for feed formulation strategies in ornamental fish culture. The enhanced growth metrics seen with Spirulina supplementation, despite a higher FCR, underscore the importance of optimizing feed blends to maintain economic viability. Barman et al. (2024) discussed the benefits of blending Spirulina with other nutrient-rich ingredients to achieve better feed conversion ratios, an approach that could potentially address the limitations noted in our study. Our results suggest that further refinement in feed formulation—perhaps by combining Spirulina with more digestible or lower-cost protein sources—could improve FCR without compromising growth.

**Conclusion**

This study demonstrates the potential of Spirulina spp. as an effective dietary supplement for enhancing the growth performance of koi fish fingerlings (C. rubrofuscus). The results reveal that koi fingerlings fed Spirulina-supplemented diets exhibited significantly greater weight gain, daily weight gain, and relative weight gain compared to those on a control diet. While the specific growth rate showed marginal differences, the enhanced growth metrics in the Spirulina group underscore its positive impact on fish development. However, the study also highlights a notable trade-off in feed efficiency, as evidenced by a higher feed conversion ratio in the Spirulina group.

Overall, these findings suggest that Spirulina can serve as a valuable feed ingredient in koi aquaculture, promoting better growth outcomes. Future research should focus on optimizing Spirulina concentrations and evaluating its long-term effects on health, survival rates, and overall production efficiency in various aquaculture settings. Understanding these dynamics will be essential for maximizing the benefits of incorporating Spirulina into aquaculture feeds while managing feed costs effectively.

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