COMPARATIVE ASSESSMENT ON GROWTH PERFORMANCE OF GOLDFISH (*CARASSIUS AURATUS LINNEAUS 1758*) FED WITH LOCALLY FORMULATED, MIXED AND IMPORTED FEED

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ABSTRACT: Feed is a critical input for improving production and minimizing the cost of production in ornamental fish farming. This study compared the growth performance and economic feasibility of different feeds on the goldfish (*Carrasius auratus*). The experiment was done in a completely randomized block design, with three treatments; imported feed (T1), locally formulated feed using mustard cake, rice bran, and wheat (T2), and a 50:50 mixture of local and imported feeds (T3). A total of 45 juvenile goldfish (8–15g) were randomly selected and assigned to three treatments (T1, T2, and T3), each with three replicates. A total of nine glass aquariums were used and the fish were fed twice daily at 2% of fish biomass. The body weight and body lengths were measured at day 0 and after every 30 days for 90 days. Likewise, pH, dissolved oxygen, and temperature were recorded twice daily. The mean percentage of weight gain was significantly higher ($p = 0.108$) in T1 (88.28 ± 5.66%) as compared to T2 (26.40± 5.58%) and T3 (39.43 ± 3.88%). The difference in the mean percentage of length gain across treatments was insignificant ($p = 0.4$), although it was highest in T1 (26.10±4.47%) followed by T2 (21.17±3.47%) and T3 (22.10±3.95 %). Moreover, the insignificant difference in the water quality parameters among treatments ($p > 0.05$) suggests no deterioration in the analyzed water quality parameters. Cost-benefit analysis showed T2 was more profitable (Nu. 274.11 per fish) compared to T1 (Nu. 270.73 per fish) and T3 (Nu. 269.33 per fish). The study concludes that better growth performance is achieved with T1 compared to T2 and T3 but T2 can significantly reduce the cost of production. Similar studies should be done to better understand the growth performance of goldfish by increasing the protein content in feed as well as including more than one protein source.

Keywords: Cost-benefit; feed; growth performance; ornamental fish, water quality.

1. INTRODUCTION

Ornamental fish are known as the “living jewels” because of their attractive colours, shapes, behaviour, and peaceful nature. Ornamental fish farming is not only an amusing leisure activity but also provides good economic opportunities for breeders. Goldfish (*Carassius auratus,* Linnaeus 1758), belonging to the family Cyprinidae of order Cypriniformes, is a freshwater species which is one of the most popular ornamental fish in the world. It has a laterally compressed body; its mouth is small and terminal, without barbels (Lorenzoni et al. 2007). Adult goldfish can reach an average length of 12 inches and display a combination of white, yellow, orange, red, brown, and black colours with an average captivity lifespan of 5-10 years (Gurung et al., 2018).

In Bhutan, ornamental fish breeding was introduced in 2012, with goldfish being a commonly bred species at the National

Research and Development Centre for Aquaculture (NR&DCA) (Wangdi, 2021). Although there are very few private breeders in the country with the first private ornamental fish farm licensed only in 2022, the emergence of ornamental fish farming presents a promising entrepreneurial venture for breeders. As demand for ornamental fish and breeding intensifies, it will necessitate a continuous supply of nutritionally balanced, cost-effective diets that provide all the essential nutrients to the fish (Bandyopadhyay et al. 2005).

Feed costs comprise up to 60% of total production costs (Gabriel et al. 2007; Ragasa et al. 2022; Thavasiyandi et al. 2017) and pose a significant financial challenge, particularly with over-reliance on expensive imported feeds and inconsistent availability of quality feed would exacerbate the financial risk for breeders (Sathyaruban et al. 2022). Moreover, knowledge of nutritional requirements and correct feed formulation in ornamental fish species like goldfish is scarce and, in most cases, this information is extrapolated from results obtained from non-ornamental fish species (Santamaría and Santamaría, 2011). Although a wide range of feeds is available for goldfish in aquariums, their cost does not make their use economical (Sathyaruban et al. 2022). The increasing cost of these feeds is due to the high cost of ingredients such as fish meal which is the main ingredient used in the formulation of commercial feeds because of its high protein content and minerals (Ye et al. 2011).

Fish feed formulation is an applied technology based on the knowledge of various feedstuff and nutrient requirements of fish. Several plant and animal derivatives can contain an appreciable quantity of protein with a good amino acid profile that can be utilized for feed formulation (Gatlin et al. 2007; Hardy, 2010). Since reducing the dependency on high-cost ingredients is key to the sustainable development of the industry, studies need to be carried out to find alternative low-cost feed ingredients and formulate nutritious and economical diets that do not rely only on a particular protein source (Ghosh and Mandal, 2015; Refstie et al. 2001). This would alleviate the dependence on high-cost ingredients (e.g., animal products) and thus help decrease the production cost. Therefore, this study was initiated to compare the growth performance and evaluate the cost-benefit of rearing goldfish under three diets viz., imported feed, locally formulated feed and a mixture of the two.

2. MATERIALS AND METHOD

2.1. Study area

The experiment was done at the National Research and Development Centre for Aquaculture (NR&DCA) in Gelephu, Sarpang. It is located at the latitude of 26°52’11” N and the longitude of 90°29’42” E, 221 metres above sea level. The average air temperature ranges between 16–30°C with in-house aquarium water temperature ranging between 18–22°C and average rainfall ranging between 1500–3000 mm (Dzongkhag Administration Sarpang 2022).

2.2. Experimental design and Feed formulation.

The experiment was set up in a completely randomized block design (RCBD) with three treatments (T1, T2 and T3), each with three replicates. The study used 45 juvenile goldfish (8–15 g; 10 months old) in nine glass aquariums, each with an area of 0.18m^2 (0.6m × 0.3m). With a stocking density of 30 goldfish/m^2, five goldfish were stocked in each aquarium. T1 received 100 % imported ornamental feed, T2 received locally formulated feed, and T3 received a 50:50 mixture of local and imported feeds. Feed for T2 was formulated using Pearson’s square method (Wagner and Stanton, 2012) with a target crude protein content of 30%. The ingredients were ground into powder form individually and then mixed according to the parts calculated (Table 1).

2.3. Feeding and Aquarium management

Feed was provided at 2% of fish biomass per day and was given twice daily at 9:00 and 16:00 hours. Each aquarium had stone aerators of the same size and water was replaced every seven days to remove feed residuals. All aquariums were kept in the same room and the experiment lasted for 90 days.

2.4. Data collection

For evaluating the growth of fish, different parameters such as body weight (g), body length (cm), percent gain in weight and length (%), specific growth rate (SGR) (% per day) and feed conversion ratio (FCR) were used. Body weight and length were recorded for all fish every 30 days. Weight (g) was measured using a digital weighing balance (Eminent company, Model: ISO9001:2024), while body length (cm) was measured on a calibrated length measuring board, ensuring minimal stress to the fish. To determine feed intake accurately, the difference between the amount fed and residue weight is typically used. However, in this experiment, due to the feed form (powdered), residue collection was impractical. Therefore, total feed intake was assumed as the total amount of feed given (i.e., 2% of fish biomass). The following equations were used to calculate the growth parameters:

$$\textit{Weight gain (\%)} = \frac{Final\ Weight\ (g) - Initial\ Weight\ (g)}{Initial\ Weight\ (g)} \times 100$$

$$\textit{Length gain (\%)} = \frac{Final\ length(cm) - Initial\ length(cm)}{Initial\ length\ (cm)} \times 100$$

$$\textit{Specific growth rate (SGR)} = \frac{Log\ final\ weight\ (g) - Log\ Initial\ Weight\ (g)}{Total\ number\ of\ days\ reared} \times 100$$ (Hopkins, 1992)

$$\textit{Feed conversion ratio (FCR)} = \frac{Total\ feed\ intake\ (g)}{Live\ weight\ gain\ (g)}$$

Water quality parameters, including temperature, dissolved oxygen (DO) and pH, were monitored twice daily at 9:00 and 14:00 hours. Temperature readings were taken using a clinical thermometer, DO levels were measured in mg/l using a digital DO meter (Lutrron DO-5509), and pH levels were recorded by a digital pH meter (Hanna HI98100).

2.5. Nutrient analysis of feed

Proximate analysis for crude protein, crude fibre, crude fat and nitrogen-free extract (carbohydrate) was done using Weende's system of analysis following the Association of Official Analytical Chemists (AOAC) protocols (AOAC 1990) at the College of Natural Resources, Lobesa. Crude protein was determined using the micro Kjeldalh method and a protein conversion factor of 6.25 was used. Crude fat was determined using the Soxhlet extraction method.

Table 1: Composition of the ingredients in the locally formulated feed (T2) using Pearson's square method.

Ingredients	Crude Protein (%)	Parts
Rice bran	13.30 (Sapwarobol et al., 2021)	2.475
Wheat grain	12.10 (Caporaso et al., 2018)	2.475
Mustard oil cake	30.90 (Sarker et al., 2015)	95.05
	Total	100

Nitrogen-free extract (NFE), which represents the carbohydrate content, was calculated by subtracting the sum of the crude protein, crude fat, total ash, and crude fibre from 100.

2.6. Data analysis

Data was recorded in Microsoft Excel and was analyzed through Statistical Package for Social Sciences (SPSS) version 26. Descriptive statistics for growth parameters were presented in means and standard error of mean (SEM). One-way Analysis of variance (ANOVA) was used to compare the growth parameters between the treatments following assumption tests such as the normality test using the Shapiro-Wilk test and Levene's test for equality of variance. Tukey’s HSD test was used for the pairwise comparison of means. Correlation between water quality parameters and performance parameters (weight and length) was done using Pearson’s correlation test. The significance level for all the analysis was set at $p < 0.05$. A time series plot for water quality parameters for each treatment was generated using the ggplot2 package in RStudio version 4.3.2.

3. RESULTS AND DISCUSSION

3.1. Nutrient composition of feed

Imported feed (T1) had the highest level of crude protein (28.00%) and ash (33.50%) compared to the other two feeds (Table 2). Despite targeting a crude protein content of 30.00%, proximate analysis yielded a notable difference which could be due to variations in raw ingredient quality and processing technique. However, T2 had a higher level of fat (6.00%) and carbohydrate (52.29%).

3.2. Growth analysis

The growth analysis included comparison of mean initial body weight and length, monthly weight and length, as well as final percentage gain in weight and length (Table 3). There was 100% survival rate in all the treatments. The result showed significant differences in the final weights across treatments at the 30 days (F (2, 42) = [12.50], $p < 0.05$), 60 days (F (2, 42) = [33.13], $p < 0.05$), and 90 days (F (2, 42) = 50.22, $p < 0.05$). The mean percentage of weight gain was significantly higher ($p < 0.05$) in T1 (88.28 ± 5.66%) as compared to T2 (26.40 ± 5.58%) and T3 (39.43 ± 3.88%). Although, the mean percentage gain in length was highest in T1 (26.10±4.47%) followed by T2 (21.17±3.47%) and T3 (22.10±3.95 %), the differences among the treatments were not significant ($p = 0.068$). Higher body weight and length gain in T1 could be due to higher protein content in the feed, as juvenile goldfish growth is highly dependent on high-protein diets (Bandhopadhyay et al. 2005). Moreover, in many studies, diets containing protein from multiple sources performed better than diets containing protein from a single source (Bardach et al. 1972; Sehgal and Thomas1985). Similarly, considering the higher growth performance of imported feed in our studies, we assume that they may contain more than one protein source, unlike locally formulated feed which had only one

Table 2: Nutrient composition of feeds.

Feed Type	Crude protein (%)	Fat (%)	Carbohydrate (%)	Ash (%)
Imported feed (T1)	28.00	3.00	35.50	33.50
Locally formulated feed (T2)	17.88	6.00	52.29	23.83
Feed mixture (T3)	25.38	4.73	38.61	31.28

Table 3: Weight (g) and length (cm) at day 0; 30, 60 and 90 days and final percentage weight and length gain of goldfish in three treatments (mean ± SEM)

Treatment	Initial (Day 0)	30 days	60 days	90 days	Percent gain
Body weight					
T1	11.25±0.44[a]	14.36±0.63[a]	18.39±0.76[a]	21.04±0.81[a]	88.28±5.66[a]
T2	10.15±0.42[a]	10.92±0.53[b]	11.65±0.59[b]	12.7±0.56[b]	26.40±5.58[b]
T3	10.25±0.59[a]	11.32±0.41[b]	12.91±0.48[b]	14.02±0.48[b]	39.43±3.88[b]
Body length					
T1	9.17±0.27[a]	10.63±0.25[a]	11±0.31[a]	11.47±0.36[a]	26.10±4.47[a]
T2	8.64±0.23[a]	9.6±0.23[b]	10.06±0.29[a]	10.41±0.28[a]	21.17±3.47[a]
T3	8.89±0.18[a]	9.61±0.32[b]	10.06±0.34[a]	10.69±0.33[a]	22.10±3.95[a]

*The values with different superscripts within the column differ significantly ($p < 0.05$).

protein source (mustard oil cake). In addition, locally formulated feeds containing higher levels of plant-based ingredients and/or complete substitution of animal proteins (T2) fail to provide consistent growth upon prolonged use (Dabrowski et al. 1986; Lim and Akiyama 1992). This may be attributed to the presence of anti-nutritional factors (ANFs) and improper amino acid balance in plant-protein-based feeds which hinder the bio-availability and digestibility of the nutrients (Francis et al. 2001; Lim and Dominy 1991).

3.3. Specific growth rates (% per day) and Feed conversion ratio (FCR)

The overall SGR (Table 4) was significantly higher ($p < 0.05$) in T1 (0.70±0.03% per day) as compared to T2 (0.25±0.05% per day) and T3 (0.36±0.03% per day). SGR in T1 remained consistent for the initial 60 days but showed a sharp decrease thereafter, whereas SGR in T2 and T3 remained relatively stable throughout the period. The overall FCR (Table 4) was significantly different ($p < 0.05$) among all the treatments; T2 (12.75±0.54), T3 (9.51±0.46) and T1 (3.98±0.99). T2 and T3 showed a sharp reduction in FCR after 30 days, whereas T1 exhibited a slight increase after 60 days.

3.4. Water quality parameters

The water temperature (Figure 1) in all the treatments ranged from 18–24°C which is in

Table 4: SGR (%/day) and FCR at different stages of the study across three treatments (mean ±SEM)

Treatment	Day 0 – 30 days	30 – days	60 – 90 days	Overall
SGR				
T1	0.81±0.07[a]	0.83±0.05[a]	0.32±0.08[a]	0.70±0.03[a]
T2	0.22±0.14[b]	0.21±0.03[c]	0.19±0.05[a]	0.25±0.05[b]
T3	0.37±0.10[b]	0.44±0.07[b]	0.10±0.02[a]	0.36±0.03[b]
FCR				
T1	2.92±0.44[c]	2.74±0.05[a]	6.29±2.49[a]	3.98±0.99[c]
T2	20.78±0.11[a]	9.78±0.10[b]	7.69±1.40[a]	12.75±0.54[a]
T3	15.94±0.58[b]	4.88±0.24[a]	7.70 ±0.56[a]	9.51±0.46[b]

*The values with different superscripts within the column differ significantly ($p < 0.05$).

the range reported by Anthony (1961) for goldfish (18–24°C) and it did not differ significantly between the treatments for all the months ($p > 0.05$). Similarly, pH (5–9) was in ideal range and also did not differ between the treatments for all the months ($p > 0.05$). The DO was in the range of 7.50–18.00 mg/l and there was no significant difference between the treatments for all the months ($p > 0.05$). However, DO showed a decreasing trend throughout the study period in all the treatments (Figure 1). The levels of DO, pH and temperature are critical water quality parameters (Boyd 2017; Jacome et al. 2011) and they have cumulative and interrelated effects on growth and health (Ariadi et al. 2019; Onada et al. 2015). The type and quality of nutrients in feeds (e.g., not properly bound) can result in the tendency for the nutrients in the feed to leach into the water before being consumed by the fish. Similarly, feeds formulated with protein sources of low biological value have been shown to exhibit a high content of non-protein nitrogen, which causes an imbalance in amino acid ratio leading to an increase in metabolic excretion, with a consequently negative effect on the water quality parameters such as pH and DO (Kosemani et al. 2017). However, in this study, there was no difference in the water quality between the

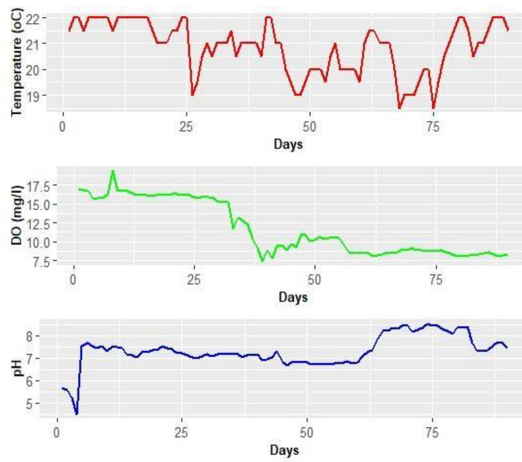

Figure 1: A time series plot of mean daily water Temperature (º C), dissolved oxygen (mg/l) content and pH level

treatments suggesting that the locally formulated feed was suitable for the feeding goldfish without causing deterioration of water quality.

3.5. Correlation analysis between water quality parameters and growth

There was a strong positive correlation between weight gain and DO ($r = 0.85$, $p = 0.001$). Additionally, weight gain and temperature showed a moderate positive correlation ($r = 0.43$, $p = 0.003$). Conversely, both weight gain ($r = -0.45$, $p = 0.002$) and length gain ($r = -0.47$, $p = 0.001$) showed moderate negative correlations with pH, implying that lower pH levels may impede fish growth (Table 5). Low pH results in non-toxic ammonium ions whereas high pH

Table 5: Pearson correlation between fish body weight and length gain, pH, dissolved oxygen (DO) and temperature.

Variable	Weight gain	Length gain	pH	DO	Temperature
Weight gain	1				
Length gain	0.493^{**}	1			
pH	-0.399^{**}	-0.098	1		
DO	0.849^{**}	0.326^{*}	-0.351^{*}	1	
Temperature	0.427^{**}	0.232	-0.164	0.405^{**}	1

** Correlation significant at $P < 0.01$, * Correlation significant at $p < 0.05$

results in a high amount of ammonia in the water, and toxic levels of ammonia can impede the ability of fish to efficiently extract energy from feed, thus leading to lethargy and even death (Hargreaves and Tucker 2004). DO is important for fish growth and if the concentration of DO decreases, it will affect the respiration and

feeding activities thus reducing the growth rate (Mallya 2007). The assimilation of feed consumed also decreases with the decrease in DO (Tom 1998). Similarly, temperature has a direct effect on fish metabolism, influencing growth and development (Islam et al. 2019; Lindmark et al. 2022). Since fish are cold-blooded, their body temperature varies depending on their environment (Volkoff and Rønnestad 2020). Thus, under optimal temperature conditions, fish use the majority of their food nutrients for growth and reproduction.

3.6. Economic analysis

The unit cost of production for feeding each feed was calculated based on the cost of feed and the amount of feed required for 1 cm growth as observed during the 90 days trial in each treatment (Table 6). The cost of production was highest for T3 (Nu.130.66/fish) compared to T1 (Nu. 129.31/fish) and T2 (Nu. 125.88/fish). The profit per goldfish was highest for T2 (Nu. 274.11) followed by T1 (Nu. 270.73) and T3 (Nu. 2269.33). The difference in the profits is mainly due to the high cost of imported feed compared to the cost of local available ingredients.

Table 6: Economic analysis (Cost and return) of goldfish reared under different treatments.

Parameter	Imported Feed (T1)	Locally Formulated Feed (T2)	Feed Mixture (T3)
Cost			
Market price of goldfish initially (8–12cm) (Nu)	120	120	120
Goldfish stocked per treatment	15	15	15
Total Cost of Goldfish	1800	1800	1800
Market price of feed (Nu/g)	1.5	0.5	1
Feed required for 1cm growth	3.88	7.36	6.7
Average Feed required to attain 21-26 cm (g).	93.12	176.64	160.8
Total feed cost (Nu.)	139.68	88.32	160.8
Total cost (fish + feed)	1939.68	1888.32	1960.8
Total Cost per fish (Total cost/15)	129.31	125.88	130.66
Return			
Market price (Nu) of one goldfish (21-26cm)	400	400	400
Survival (nos.) at the end of trial	15	15	15
Total Revenue from sale of goldfish (Nu)	6000	6000	6000
Profit from sale of goldfish (Nu)	4061	4111.68	4040
Profit per goldfish (Nu)	270.73	274.11	269.33

4. CONCLUSION AND RECOMMENDATIONS

There was a significant difference in the overall weight gain of the goldfish among the three groups, with significantly higher growth reported from imported feed (T1). The difference in overall gain in length was not significant. In comparison to other treatments, significantly low FCR and significantly higher SGR for T1, clearly indicates better growth performance of imported feed over the other feeds. In terms of economic feasibility, the study concludes that feeding locally formulated feed (T2) is economically feasible with a better profit margin. The study concludes that better growth performance is observed in goldfish when fed with imported feed (T1) compared to locally formulated feed (T2) and feed mixture (T3) but feeding locally formulated feed can reduce the cost of production and increase profit margin for goldfish farming. Moreover, locally formulated feed did not deteriorate water quality. In consideration of present findings, similar studies should be done to evaluate the growth performance of goldfish or other available ornamental fish species in Bhutan by increasing the protein content and by more than one protein source during the feed formulation.

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