Potential Effects of Live and Nutrient-Enhanced Food on Growth Performance and Biochemical Composition of Blue Acara (*Andinoacara pulcher*)

ABSTRACT Fish food and feeding play an important role in understanding the rate of growth, development and reproduction in ornamental fish culture. The current study evaluated the impact of different types of food on the growth of Ornamental fish, *Andinoacara pulcher.* A comparative analysis of commercial, prepared, and live food was conducted in three feeding groups. For live feed, Artemia larvae were cultured from Artemia seeds, and fed. The growth analysis and biochemical composition of the fish were estimated for 60 days of feeding and observation. From the results, the fishes fed with live feed attained maximum growth when compared to other commercial as well as prepared feeding groups. A significant increase in weight and length was recorded in fishes fed with all three types of food. There is a well-defined relationship between the rate of growth and the type of food consumed. The protein, carbohydrate, and fat content of fish revealed a higher biochemical composition. In conclusion, the growth and biochemical study in the present investigation indicated that the live feed contains good constituents of vital nutrient substances that promote the growth and protein content of ornamental fish, Blue Acara.

Comment [MK1]: Describe in detail the increase in weight and length of the ornamental fish.

Keywords: Andinoacara pulcher; Blue Acara; Artemia; Live feed; Ornamental Fish; Growth performance.

INTRODUCTION

Ornamental fishes are often referred to as living jewels due to their beautiful colours, forms, and behavior, and are kept in aquaria or garden pools for entertainment and pleasure, making them one of the most popular hobbies in the world, alongside photography (Hoseinifar *et al.* 2023). People are increasingly interested in purchasing attractive fish species for decorative purposes, noting their appealing traits and unique attributes. These peaceful creatures are typically small in size, come in various attractive colors, and can thrive in smaller environments. In India, ornamental fish make up about 1% of the total ornamental fish trade (Yadav and Sharma, 2022). Ornamental aquaculture offers many benefits such as increased global demand, reduced impact on wild stocks, more efficient production, and economic support for smaller middle-class communities (Saba *et al.* 2021). Aquarium fish are more expensive than food fish, with marine ornamentals being ten times costlier than their freshwater counterparts. However, there are also risks associated with aquaculture, including the introduction of non-native species, user conflicts, disease infections, diet formulation, and so on (Luna *et al.* 2023). To achieve economic farming of ornamental, it is essential to determine the appropriate and precise diet and prepare low-budget artificial feeds from already available food ingredients (Avdesh *et al.* 2012). Feeding habits and food play a vital role in understanding the growth rate, population density, maturity of gonads, and other metabolic functions of aquatic organisms. Feeding is a crucial function for aquatic animals because growth, development, and reproduction release a high amount of energy, which enters the organisms as food. The availability and quality of food resources greatly affect the life cycle of fish in terms of maturation and reproduction (Assan *et al.*, 2021). When it comes to feeding fish, the right routine is important for their growth and health. If they don't get enough food, they can stop growing and become more vulnerable to diseases. There are several factors to consider in creating the best feeding routine for fish, such as the amount and quality of food, feeding practices, and frequency, time of feeding, and specific diet. The ideal feeding ratio can vary depending on the species, age, size, environmental factors, cultivation method, and quality of the feed (Junior *et al.* 2023, Yang *et al.* 2023).

Artificial feeds can help provide fish with concentrated nutrients that may not be easily found in natural food. The recent research recommended supplementing artificial feed with natural food in fish culture to balance out their diet. Artemia has become a more valuable larval diet due to significant progress in the past decade (Lahnsteiner, 2023). Wee *et al.* (2021) reported that Artemia is a type of live feed that can be sustainably cultured for ornamental fish. When Artemia is bio-encapsulated with spirulina *Arthrospira platensis*, it gains immunostimulant properties that can further enhance the development, nutrition, and welfare of the fish. By using in-house cultures of bio-enriched live feeds, it can reduce costs while improving the immunity of the fish. The nutritional profile of Artemia depends heavily on its diet, but it is an easily harvestable feed that can be a great source of nutrition for ornamental fish.

When it comes to nutrients, the carbohydrate utilization of fish varies between fish species as well as carbohydrate sources. Fish are known to have a limited ability for digestion and metabolism of carbohydrates and hence, excessive intake of this nutrient may result in nutritional problems (Arenas *et al.* 2021). Excess carbohydrates reduce the growth rate and are often accompanied by poor feed utilization. In general, herbivorous fish are more capable of utilizing dietary carbohydrates than carnivorous and omnivorous fish. Thus, high dietary carbohydrate consumption may increase the incidence of diseases and affect the antioxidation ability of the fish (Giri *et al.* 2021). Protein is essential for the growth of fish, and it also regulates their energy balance. If the amount of protein in their diet is excessive, or the energy level from non-protein sources is insufficient, it can lead to problems. Therefore, it's crucial to develop diets for fish that have a balanced amount of protein and energy (Siddik *et al.* 2021; Assan *et al.* 2021).

To ensure proper energy utilization, it is important to include adequate levels of lipids in the diet of fish. This helps to minimize the breakdown of dietary protein. However, if the dietary lipid levels are either too high or too low, it can negatively impact the growth performance of fish, increase the conversion ratio of feed to body weight, and result in the deposition of excess fat (Torrecillas *et al.* 2021). The amount of dietary carbohydrates can influence a fish's ability to use dietary lipids as a non-protein energy source. A growing trend in fish feeds involves using higher levels of lipids in the diet. This approach reduces the high cost of feed by partially sparing protein (Xie *et al.* 2021). On the other hand, excessive fat deposition in the liver can decrease fish health, quality, and shelf life of the final product. Hence, suggesting a food with a balanced amount of protein, carbohydrates and lipids with more digestibility is the need of the hour. In this sense, Artemia is considered a potential candidate in dietary inclusions to potentiate fish growth and health status. The aim of the current investigation is therefore to evaluate the effect of commercial, prepared and live feed on growth performance and biochemical composition of ornamental fish, *A. pulcher*.

EXPERIMENT

Experimental animal

Andinoacara pulcher, a species of convict cichlid of the family, Cichlidae is selected as the experimental fish for this study.

Live feed (Artemia) culture

Artemia, also known as brine shrimp is selected as the live feed for this experiment. For Artemia culture, 35 grams of salt was added to one liter of fresh water, and the alkaline pH (pH 7.5- pH 8.5) was maintained using a pH meter and sodium bicarbonate. Meanwhile, the Artemia seeds were soaked in fresh water for 30 minutes to soften their outer cells for easy hatching. After 30 minutes of soaking, the artemia seeds were filtered through a 100-micron mesh and introduced into the culture tank containing salt water. The culture tank was then connected to an aerator. After 24 hours, the Artemia seeds had hatched, and the hatched larvae were filtered using a filter tube. Finally, since the fishes were freshwater species, the salt water was filtered out, and the fishes were exclusively fed with Artemia.

Prepared fish feed

The various components required for the feed were dried, powdered, and mixed together. Water was added to form a soft dough, which was then boiled in a closed water bath for an hour. Once cooked, the dough was allowed to cool without removing the lid. Vitamins, minerals, and fish oil were added and mixed thoroughly. The mixture was then pressed through a pelletizer with a perforated disc. The resulting noodles were dried and broken into pieces, ensuring that the pellet feeds were free from moisture. The dried pellets were stored in an airtight container for daily use (Table 1). Proximate composition analyses of test diets were performed according to AOAC, (1990) with three replicates each.

Table 1. Ingredients in nutrients enriched prepared feed for *A. pulcher.*

Ingredients	Quantity
Rice bran	400 g
Boiled peanuts	300 g
Dry fishes	100 g
Carrot	100 g
Beetroot	100 g
Spleen Amaranth	100 g
Egg	1
Vitamin, mineral mix	20 g
Fish oil	10 g
Salt	10 g

Commercial fish feed

Taiyo, a well-known brand of commercial fish feed, was sourced from a nearby supply store and was used in this study.

Experimental design

A lot of the experimental fish, the round *A. pulcher* was purchased from Tamil Nadu Dr. J. Jayalalitha Fisheries University, Parakkai, Kanyakumari District, Tamilnadu, India and transported safely to the laboratory in oxygenated bags. Care was taken to avoid the stress of overcrowding. They were acclimatized to the laboratory conditions in a plastic trough with water for 10 days. Fishes of the same sizes were taken to find out the effect of food on growth and body composition. About 45 healthy young stage fishes of uniform size were taken and divided into three groups with 15 each. Three groups were named as group A, group B, and group C. Group A was fed with live feed (Artemia), group B with prepared feed, and group C with commercial feed (Taiyo). Each group was further subdivided into 3 groups with 5 fishes. Thus, the experiment was carried out in triplicates. Before the fish were released into the experimental troughs, they were weighed using balance and measured length using a scale. The experimental fishes were fed daily 8.00 A.M, 1.00 P.M, and 6.00 P.M with Artemia (Group A), prepared feed (Group B), and taiyo- commercial feed (Group C) respectively *ad libitum*. The water was renewed once every four days. At the time of changing water, to undisturb the fish, the water in the experimental tank was siphoned out along with the wastes and then fresh water was added uniformly. The fish were grown for 60 days. The growth in terms of weight and body length (total and standard length) was measured at a 15-day interval throughout the experimental period of 60 days. Throughout the feeding trial, various water quality parameters were monitored to assess the overall quality of the water. This included daily monitoring of water temperature, dissolved oxygen (DO), and pH levels using a multi-parameter photometer.

Growth and biochemical analysis

The experimental fishes were weighed using a weighing machine and their length was measured periodically. The weight loss or gain i.e. growth due to different types of food intake was found out and expressed in unit weight. Growth in terms of length was also calculated by subtracting the initial length of the fish from the final length of the fish.

Growth in terms of wet body weight (weight gain) = Final weight - Initial weight

Growth in terms of body length (length gain) = Final length - Initial length

Specific Growth Rate (SGR) % = $\frac{\text{Final weight} - \text{Initial weight}}{\text{Duration (Days)}} \times 100$

After the 60th day of rearing the fishes were sacrificed and dried to measure the body composition of protein, carbohydrate and lipid.

RESULTS

The present attempt clearly shows the variation produced by the different feed types on the growth and major biochemical composition of the ornamental fish, *A. pulcher*. The proximate composition of the feed such as crude protein, crude lipid, and crude ash were 36.59 %, 9.43 %, and 12.93 % respectively (Table 2). The feed parameters such as moisture (11.81 %), floatability (98.33 %) and water stability (78.75 %) were tested before the feeding experiment. Conversely, the hydrological parameters including temperature, pH, and dissolved oxygen (DO) were measured during the trial (Table 3). In the case of water temperature, pH, and dissolved oxygen, no remarkable variances were observed among the treatment groups.

Table 2. Proximate composition and feed parameters (% dry matter basis) for prepared feed.

Proximate Composition/Parameters	Diets (%)
Crude protein	36.59
Crude lipid	9.43
Crude ash	12.93
Moisture	11.81
Floatability	98.33
Water stability	78.75

Table 3. Quality parameters of water used in the experiment (n = 3). Results are presented as mean ± standard deviation.

S. No	Water Quality Parameters	
1.	pH	7.1± 0.2
2.	Temperature (ºC)	28.3 ± 0.4
3.	Dissolved Oxygen (mgL^{-1})	5.9 ± 0.5
4.	Ammonia (mgL^{-1})	0.02 ± 0.01

The impact of different feed on the growth

The fishes fed on live feed (group A) attained maximum growth than those of the other feed groups, B and C. The impact of different feed on the growth of *A. pulcher* for a period of successive 15, 30, 45 and 60 days of the experiment showed that all groups exhibited more or less similar growth in terms of weight and length (Fig. 1). The maximum growth is observed in the live feed (group A) followed by the prepared feed group. The SGR (%) was found to be maximum at group A, followed by group B and C (Table 4). The impact of different types of fish feed on fish growth on the 60th day of the experiment is summarized in Table 4 and Fig. 2 & 3. The maximum growth was observed in the live feed (group A). The prepared feed fishes also showed better growth compared to commercial feed fishes (Fig. 4).

Table 4. The impact of different feeds on the growth of *A. pulcher* during the experimental period of 60 days.

Group	Initial			60^{th} day			SGR (%)
	Weight (gm)	Standard length (cm)	Total length (cm)	Weight (gm)	Standard length (cm)	Total length (cm)	
A	0.62 ±0.22^{c}	2.6 ± 0.45^{b}	3.6± 0.53^{a}	1.5 ± 0.30^{b}	3.5 ± 0.53^{ab}	5.5 ± 0.57^{c}	1.46
B	0.61 ±0.21^{a}	2.9 ±0.38^{a}	3.7 ±0.37^{b}	1.3 ±0.25^{ab}	3.7 ± 0.42^{b}	5.0 ± 0.42^{a}	1.15
C	0.57±0.12^{a}	2.8 ± 0.34^{a}	3.5± 0.38^{a}	1.00 ±0.15^{a}	3.4± 0.38^{a}	5.5 ± 0.39^{b}	0.71

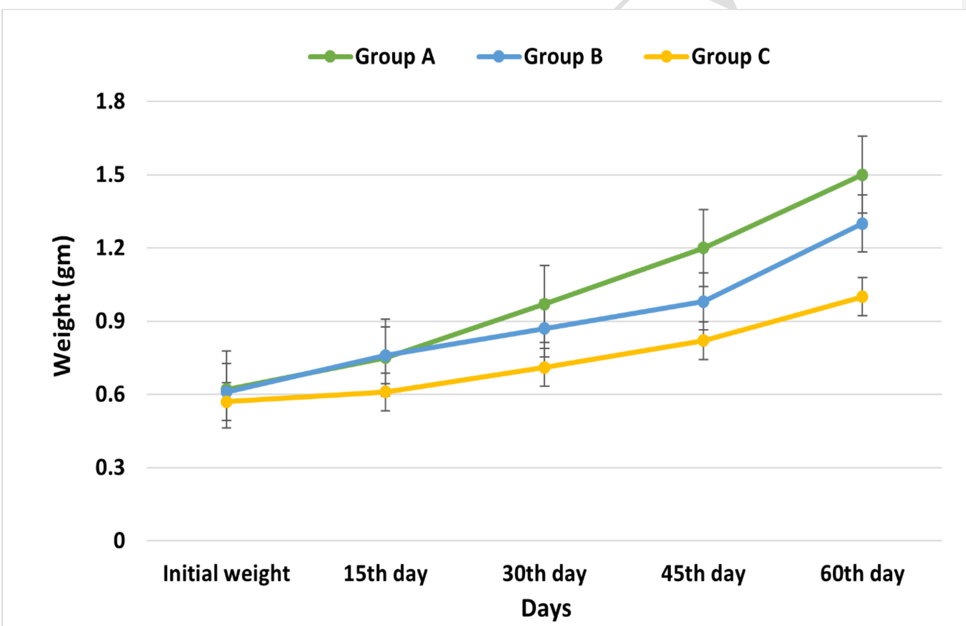

Fig. 1. The impact of different feed on the weight of *A. pulcher* for successive 15, 30, 45 and 60 days of the experiment.

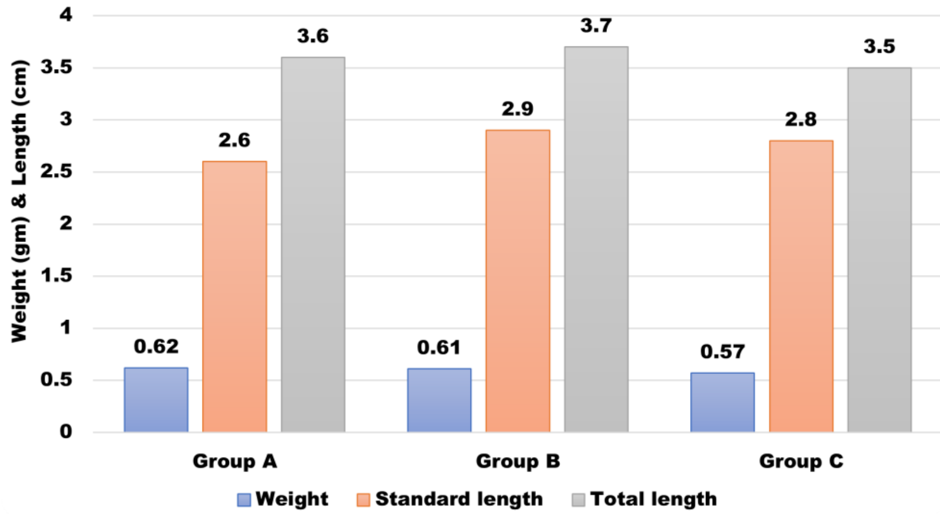

Fig.2. Initial body wet weight and body length of the fish, *A. pulcher*. The value represents the average performance of individuals.

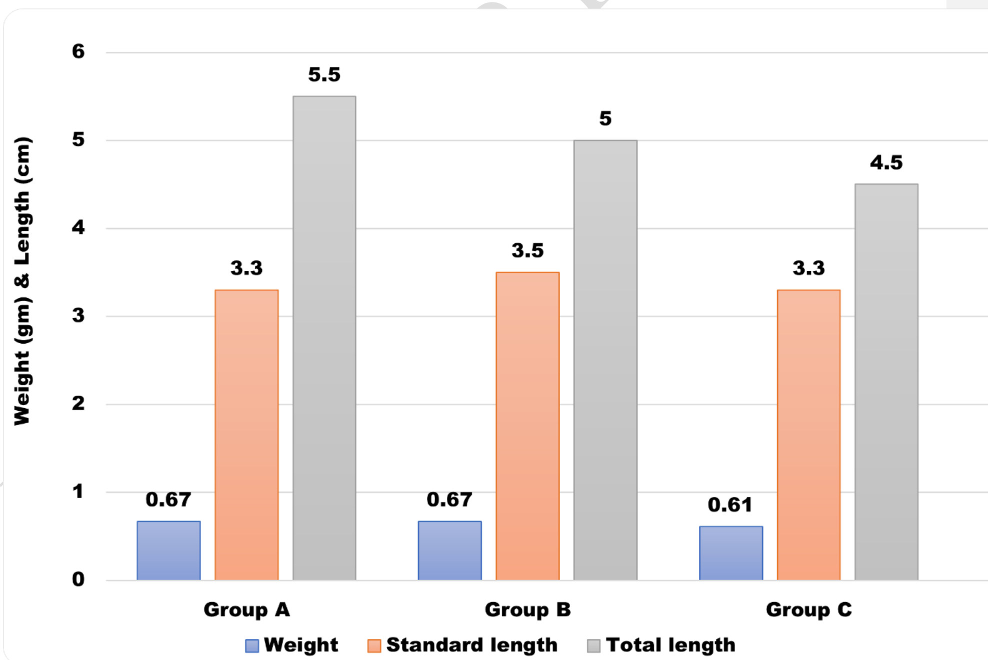

Fig. 3. The weight and length of the fish, *A. pulcher* fed on different types of food on the 60^{th} day of the experiment.

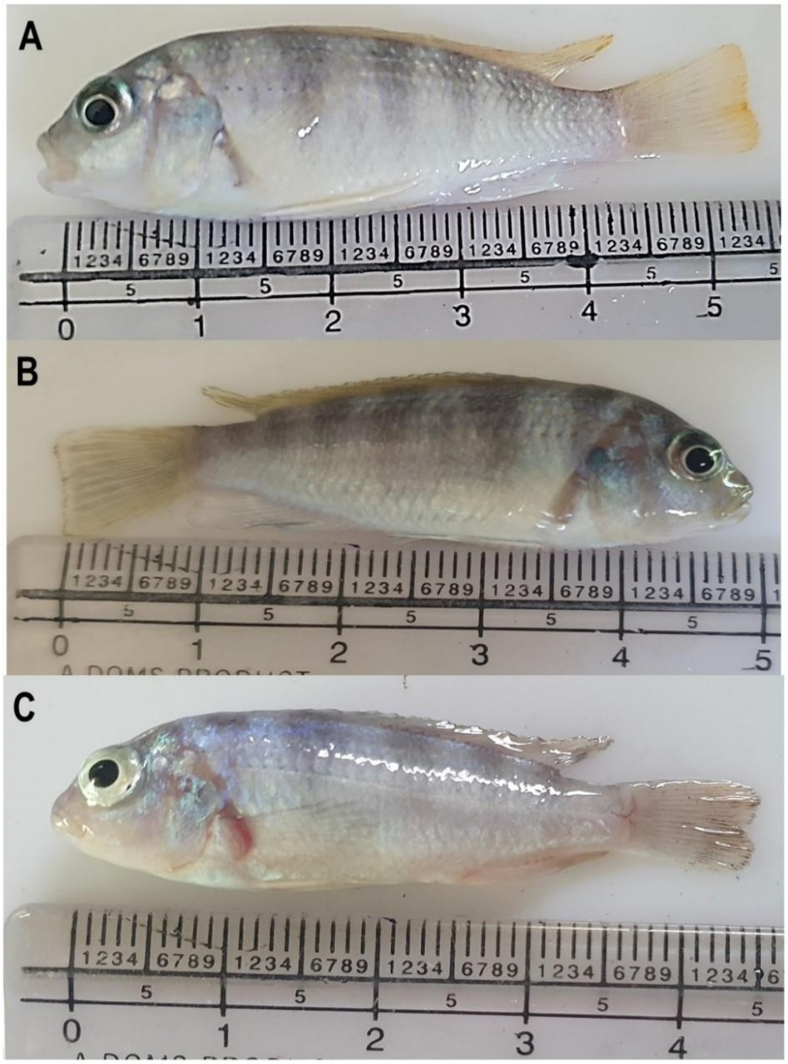

Fig. 4. Growth performance of *A. pulcher* fed on different types of food, (A) Group A- Live feed, Artemia; (B) Group B- Nutrient-enriched prepared feed and (C) Group C- Commercial feed at the 60th day of the experiment.

The impact of different feeds on the body composition

The experimented fishes were sacrificed and the whole-body composition parameters such as protein, lipid, ash, and moisture contents were analyzed and presented in Table 5. The protein percentage of the fish increases from group A to group C. There were no significant differences between the two diets, but the growth of fish was significantly influenced by the lipid level in their feeds. The ash content in the body tissues showed statistical differences among the three feed groups.

Table 5. Proximate composition of the whole body (wet basis) of fish with different experimental feeds (n=3). Results are presented as mean ± standard deviation.

Whole Body		**Diet (%)**	
Parameters	**Group A**	**Group B**	**Group C**
Protein	23.94± 0.70	22.85 ± 0.58^{ab}	21.48 ± 0.19^{a}
Lipid	8.11 ± 0.15^{a}	6.81 ± 0.04^{b}	7.09 ± 0.20
Ash	2.63±0.19	2.57 ± 0.18	2.17 ± 0.38
Moisture	65.47 ± 0.65^{a}	64.32 ± 0.45^{a}	63.02 ± 0.93^{b}

DISCUSSION

The knowledge of fish biology and the principal factor determining the growth and body composition is important when considering the maintenance of fish in a constrained environment (Xie *et al.* 2021). In addition, the water quality parameters such as pH, dissolved oxygen (DO), and NH_3 were all found to be within the suitable range for supporting the normal growth and survival of *A. pulcher*. Generally, fish can survive in pH levels ranging from 6 to 7. The average pH value of the treatments remained relatively stable, ranging from 6.5 to 7.5, which is suitable for the appropriate growth and development of *A. pulcher*. The dissolved oxygen in water plays a vital role in fish culture, and during the trial, the dissolved oxygen (DO) was always above 5 mg/L, which was deemed suitable for the growth of *A. pulcher*. Additionally, the mean NH_3 during the trial was 0.02 mg/L, which is within the suitable range for *A. pulcher* development. Fish growth is essentially unlimited, as it is difficult to determine the maximum body size of a particular species. Fish grow throughout their lives (Arenas *et al.* 2021).

The purpose of this study was to investigate growth performance and the body composition of *A. pulcher*, fed with three different feeds namely, the live feed artemia (group A), the prepared feed (group B) and the commercial feed (group C). Growth in terms of weight gain was highest in the fish fed with feed A which contained the live feed. The development of fish in culture conditions depends upon the availability of essential nutrients in the diet, digestibility and its effect on meat of fish. These parameters are considered as the basic growth of the fish (Khan *et al*., 2004). The feeding behavior and mechanism of feeding in fishes, however, have been reported to be very complicated with fish feeding (Wee *et al.* 2021).

An increase in weight and length was recorded in fishes fed with all three types of food. This showed that all of the experimental diets contain growth factors. This observation is in agreement with the findings of Sogbesan *et al.* (2006). There is a well-defined relationship between the rate of growth and the type of food consumed. In the present study, a high growth rate is observed with the live feed. The present study concentrates on the estimation of protein, carbohydrate, and lipid levels of the experimental fish to know the effect of different feeds. Marked variation in the level of protein, lipid, and carbohydrate was observed in the fishes. Total protein was high in group A, fish fed with live feed. The results of the present study showed that live feed improved fish growth and protein content in the body. Our findings were in line with the results of Zhou and Yue (2010) who reported that fish meal could be successfully substituted with other ingredients in feeds.

Protein is a crucial component of living tissues, serving both metabolic and structural purposes. Therefore, any alteration in its levels can indicate an impact on the metabolic functions that are necessary for maintaining a healthy physiological state. In this study, the protein content was high in the live feed (group A). Lipids are organic substances that cannot dissolve in water but can dissolve in organic solvents. They are significant dietary components due to their high-calorie content and the presence of fat-soluble vitamins and essential fatty acids. Lipids are found in the cytoplasm and cell walls, as well as in specialized areas of the body where they are stored as fat deposits. The lipid level in the experimental fish, *A. pulcher* was observed maximum in the group feed on the prepared feed (group B). This may be due to the fat-rich ingredients. It is important to provide food that promotes fast growth and is rich in biochemical constituents because the chemical composition of food affects both wild and reared populations (Assan *et al.* 2021). It is clear from the above discussion that these feeds are highly nutritious. Davis *et al.* (1999) stated that the supplementary diet of triglycerides reduces excessive lipid deposition in fish and the exception of high lipid diet may result in poor performance of fish. Olsen *et al*. (1999) worked on *A. pulcher* fed on linseed oil and soya bean lecithin, showing epithelial damage and lipid droplets in the intestinal lumen with increased levels of lipid. This study demonstrated the benefits of using live feed and nutrient-enhanced prepared food on commercial farms. These methods improve fish growth rate and biochemical composition, resulting in significant economic benefits for aquaculture farms.

CONCLUSIONS

The use of Artemia live fish feed has been found to significantly improve both the growth performance and cost-effectiveness of fish farming. The body composition of *A. pulcher* was increased, which may enhance the immunity of the fish. The prepared feed is recommended for the growth of ornamental and freshwater fish.

Comment [MK2]: The conclusion section should explain the findings of each feed, then explain its advantages and recommendations.
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