Asian Journal of
Biological Sciences

OPEN ACCESS

Studies on the Influence of Artificial Fish Feed on the Growth of the Fingerlings of the Spotted Tilapia, *Pelmatolapia mariae*

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ABSTRACT

Background and Objective: Aquaculture is a widely practised agricultural method globally, which involves raising aquatic organisms in suitable environmental conditions. Its main objective is to meet the increasing demand for fish and reduce reliance on fish imports and fishery products. **Materials and Methods:** In the present study, spotted tilapia, *Pelmatolapia mariae*, obtained from the local market were fed with artificial diets, namely Diet 1, Diet 2, Diet 3, Diet 4 and Diet 5. Over a period of 28 days, the live weight, standard length, total length and biochemical composition (protein, carbohydrate and lipid) of the fish were monitored every 7 days. **Results:** After the 28 days period, the control group exhibited higher total length and standard length, while Diet 5 resulted in a higher live weight. Fish fed with Diet 5 also showed a higher protein content. Carbohydrate content was found to be higher in fish fed with Diet 3 and the control group. On the other hand, the control group had a higher lipid content. **Conclusion:** Considering the superior growth and biochemical constituents observed in fish fed with Diet 5, it is recommended to incorporate chicken wastes such as legs and intestines, as well as agricultural byproducts like cauliflower leaves and moringa, into artificial fish feed. This can potentially enhance the overall performance and productivity of aquaculture systems.

KEYWORDS

Spotted tilapia, *Pelmatolapia mariae*, fingerlings, growth, fish feed, aquaculture

INTRODUCTION

Aquaculture is the fastest growing industry and now it is being rehearsed in numerous corridors of the world. In the world, Asia contributes about 90% of the world's aquaculture production. Seven countries including India, Bangladesh, China, Indonesia, Vietnam, Japan and Thailand contribute much since 2000[1]. In the past 50 years, Indian aquaculture has grown at a faster rate and in some years the growth rate in aquaculture was recorded as high as 9%. Freshwater aquaculture is known as raising, breeding and rearing of aquatic animals and plants in ponds, lakes, reservoirs and rivers[2]. In 19th century, many focused on Brackish water aquaculture but later due to environmental changes many practised freshwater aquaculture. The three Indian major carp namely, catla (*Catla catla*), rohu (*Labeo rohita*) and mrighal (*Cirrhinus mirgala*) are mostly grown in freshwater aquaculture. They contribute the bulk of production with over 1.8 million tons[3].

ISSN: 1996-3351 (Print)
https://doi.org/10.3923/ajbs.2024.128.137

Received: 22 Nov. 2023
Accepted: 20 Feb. 2024
Published: 31 Mar. 2024

Tilapia is a popular and well-known fish which is substantially found in tropical fish farms. Spotted tilapia is placed under the class Actinopterygii and the order Perciformes and belongs to the family Cichlidae. They are ray-finned fishes mostly found in freshwater and brackish water. They live in stagnant and flowing waters in rocky or mud bottom areas[4]. Tilapia ranks as the third most important cultured fish group next to carp and salmonids. They are cultured mostly in tropical and subtropical countries. Nearly 100 countries are raising tilapia[5]. They feed on phytoplankton, zooplankton, periphyton, larval fish and detritus. They are continuous diurnal feeders which could be microphagous or macrophagous based on their genus. Adult tilapia is herbivorous but they get adapted to the commercial diets provided to them. Mostly spotted tilapia are herbivorous and they feed on higher plants and algae but sometimes they feed on insects and shrimps along with their eggs. Several environmental factors are responsible for the growth of tilapia. They easily adapt to environmental factors like salinity, temperature, dissolved oxygen and pH[6-8].

Fish is a crucial component of the human diet, playing a significant role in India. With over half of the country's population consuming fish, certain states such as Assam, the Northeastern States, West Bengal, Odisha, Goa and Kerala have a staggering consumption rate of over 90%[9]. Consumption of fish by the people increases by 20 kg per capita. More than 3.1 billion people consume fish as a food because it contains a lot of nutrients. The production of fish increased gradually depending on their need[10]. For fast growth and high yield of fish, a balanced diet should be given. A well-balanced prepared food is essential and it is the most important for the betterment of culture. A well-balanced diet requires all nutrients including proteins, carbohydrates, lipids, vitamins and minerals[11]. The edible fish farmers and ornamental fish farmers purchase their feed for fish from commercial manufacturers. But small ornamental fish farms need specialized fish feed only in small quantities. Producing specialized fish feed and exporting it in small quantities causes loss to commercial manufacturers. To avoid it, ornamental fish farmers themselves began to prepare the fish feed with common ingredients[12,13]. In this context, the present study has been planned to find out the efficiency of different artificially prepared diets on the growth enhancement of *Pelmatolapia mariae*.

MATERIALS AND METHODS

The study was carried out in Zoology Laboratory, The American College, Madurai, Tamil Nadu, India from December, 2018 to April, 2019. The tilapia was procured from a fish market in Arumbanur, Madurai, Tamil Nadu, India and subsequently transported to the laboratory. Implementing a triplicate setup, 10 fish were allocated to each tank, resulting in a total of 120 fish distributed across 12 tanks. Different artificially prepared diets along with control were used to feed the fish. Groundnut oil cake and rice brawn were used as the control diet. The five different artificially prepared diets were given to the fish (Fig. 1a-f).

The live weight, whole length and standard length of the fish were determined. The measurements were taken once in 7 days, for 28 days. After every 7 days, protein, carbohydrate and lipid content have been estimated in the fish for up to 28 days using standard procedures. The biochemical composition of the fish before and after the experiment was also determined[14].

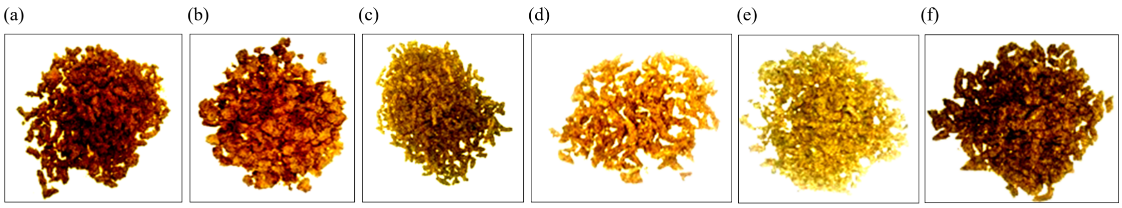

Fig. 1(a-f): Diets used in the experiment, (a) Control, (b) Diet 1, (c) Diet 2, (d) Diet 3, (e) Diet 4 and (f) Diet 5

RESULTS

Table 1 shows the ingredients that are used in the preparation of the artificial diets. The control diet contained the groundnut oil cake and rice bran. The Diet 1 had the composition of groundnut oil cake, rice bran and chicken intestine. Diet 2 had groundnut oil cake, rice bran and moringa leaves. Diet 3 contained groundnut oil cake, rice bran and chicken leg. Diet 4 was prepared with groundnut oil cake, rice bran and cauliflower leaves. Diet 5 had groundnut oil cake, rice bran, chicken intestine, moringa leaves, chicken leg and cauliflower leaves.

Table 2 exhibits the biochemical composition (protein, carbohydrate, lipid) of the diet. The protein content was higher in the Diet 5 followed by Diet 2. Diet 2 had higher carbohydrate content followed by Diet 4. The lipid content was higher in control diet followed by Diet 5.

The total length of the spotted tilapia when fed with different diets is shown in Table 3. Control fish showed the highest growth after 28 days followed by Diet 1 and Diet 5. During this experiment, minimal growth was observed in Diet 4. The maximum total length of 6.05±0.33 cm was observed after 28 days for control and the minimum total length of 5.35±0.44 cm was observed after 28 days for Diet 4.

Table 4 shows the standard length of the spotted tilapia observed during the experiment. Control fish exhibited the highest standard length followed by fish fed with Diet 1 after 28 days. Fish fed with Diet 3 and Diet 5 exhibited equal standard length. The maximum standard length of 5.15±0.75 cm was observed after 28 days for control fish and the minimum standard length of 4.3±0.45 cm was observed after 28 days for fish fed with Diet 4.

The live weight of spotted tilapia observed during the experiment is exhibited in Table 5. There was a gradual increase in growth when fishes were fed with Diet 5. Fish fed with Diet 2 exhibited the second highest growth followed by that of Diet 1. The maximum live weight of 3.47±0.49 g was observed after 28 days in fish fed with diet 5 and minimum live weight of 2.8±0.78 g was observed after 28 days in fish fed with diet 3.

Table 1: Ingredients (g/kg) used in the preparation of fish diets

Ingredients	Control	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Groundnut oil cake	500	400	400	400	400	400
Rice bran	500	400	400	400	400	400
Chicken intestine	-	200	-	-	-	50
Moringa leaves	-	-	200	-	-	50
Chicken leg	-	-	-	200	-	50
Cauliflower leaves	-	-	-	-	200	50

Table 2: Biochemical components (mg/g dry weight) of fish diets

Parameter	Control	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Protein	2.8	4.8	7.75	7.6	5.45	8.45
Carbohydrate	48	41	52.5	48	50	42.5
Lipid	0.1131	0.0445	0.0468	0.0458	0.0404	0.0513

Table 3: Total length (cm) of the spotted tilapia, *Pelmatolapia mariae* fed with the artificial diets for 28 days

	Experimental period (days)				
Diets	0	7	14	21	28
Control	4.34±0.05	4.55±0.75	5.17±0.63	5.80±0.48	6.05±0.33
Diet 1	4.34±0.05	4.25±0.64	4.77±0.55	5.15±0.45	5.97±0.37
Diet 2	4.34±0.05	4.72±0.26	4.95±0.36	4.95±0.83	5.62±1.05
Diet 3	4.34±0.05	4.75±0.31	4.87±0.78	4.95±0.34	5.45±0.53
Diet 4	4.34±0.05	4.22±0.53	4.72±0.66	5.42±0.89	5.35±0.44
Diet 5	4.34±0.05	4.75±0.23	5.02±0.35	5.85±0.51	5.65±0.26

Table 4: Standard length (cm) of the spotted tilapia, *Pelmatolapia mariae* fed with the artificial diets for 28 days

	Experimental period (days)				
Diets	0	7	14	21	28
Control	3.42±0.13	3.70±0.53	4.15±0.51	4.60±0.48	5.15±0.75
Diet 1	3.42±0.13	3.25±0.50	3.87±0.37	4.02±0.42	5.05±0.58
Diet 2	3.42±0.13	3.77±0.17	4.00±0.32	3.90±0.76	4.65±1.03
Diet 3	3.42±0.13	3.77±0.35	4.02±0.55	3.97±0.26	4.52±0.63
Diet 4	3.42±013	3.50±0.58	3.82±0.53	4.42±0.63	4.30±0.45
Diet 5	3.42±0.13	3.75±0.28	4.05±023	4.65±0.62	4.52±0.17

Table 5: Live weight (g) of the spotted tilapia,*Pelmatolapia mariae* fed with the artificial diets for 28 days

	Experimental period (days)				
Diets	0	7	14	21	28
Control	2.18±0.20	2.05±0.58	2.47±0.75	3.02±1.10	3.25±0.70
Diet 1	2.18±0.20	2.02±0.65	1.97±0.65	2.32±0.64	3.25±0.34
Diet 2	2.18±0.20	1.90±0.14	2.00±0.31	2.10±0.81	3.32±1.04
Diet 3	2.18±0.20	1.95±0.17	2.10±0.67	2.12±0.33	2.80±0.78
Diet 4	2.18±0.20	2.15±0.71	1.80±0.64	3.05±0.93	2.97±0.67
Diet 5	2.18±0.20	2.02±0.41	2.30±0.55	3.17±0.96	3.47±0.49

Table 6: Protein content (mg/g dry weight) of the spotted tilapia, *Pelmatolapia mariae* fed with the artificial diets for 28 days

	Experimental period (days)				
Diets	0	7	14	21	28
Control	3.04	1.70	3.15	3.45	2.80
Diet 1	3.04	2.30	4.60	2.60	4.80
Diet 2	3.04	2.45	3.85	2.40	7.75
Diet 3	3.04	1.95	2.65	4.25	7.60
Diet 4	3.04	2.50	3.70	4.00	5.45
Diet 5	3.04	3.40	5.75	4.40	8.45

Table 7: Carbohydrate content (mg/g dry weight) of the spotted tilapia, *Pelmatolapia mariae* fed with the artificial diets for 28 days

	Experimental period (days)				
Diets	0	7	14	21	28
Control	3.4	4.0	4.0	69.5	65.0
Diet 1	3.4	6.5	5.4	76.0	40.0
Diet 2	3.4	5.3	8.5	57.5	61.0
Diet 3	3.4	6.1	7.6	54.5	65.0
Diet 4	3.4	4.1	3.7	61.0	40.0
Diet 5	3.4	4.0	8.5	63.0	54.5

The protein content of the spotted tilapia during the experiment is exhibited in Table 6. After 28 days, fish fed with Diet 5 showed the highest protein content followed by fish fed with Diet 2 and 3. Fish reared with Diet 1 showed less protein content followed by control.

Table 7 shows the carbohydrate content of fish reared during the experiment. Fish fed with Diet 3 and control fish had high carbohydrate content followed by fish reared with Diet 2 and 5 after 28 days. Fish cultured with Diet 1 and 4 exhibited low carbohydrate content.

Table 8 shows the lipid content of the spotted tilapia during the experiment. The lipid content was high in fish cultured in control diet followed by fish fed with Diet 2 and 4 after 28 days. Fish cultured with Diet 1 showed less amount of lipid content.

Table 8: Lipid content (mg/g live weight) of the spotted tilapia, *Pelmatolapia mariae* fed with the artificial diets for 28 days

	Experimental period (days)				
Diets	0	7	14	21	28
Control	0.0522	0.0312	0.1183	0.0732	0.1077
Diet 1	0.0522	0.0033	0.0691	0.0102	0.0069
Diet 2	0.0522	0.2278	0.0206	0.1131	0.0187
Diet 3	0.0522	0.0254	0.0098	0.0072	0.0084
Diet 4	0.0522	0.2301	0.0118	0.0221	0.0125
Diet 5	0.0522	0.0092	0.0019	0.0098	0.0110

Table 9: Average daily weight gain (WG) (g) of the spotted tilapia, *Pelmatolapia mariae* reared using artificial diets for 28 days

	Experimental period (days)			
Diets	7	14	21	28
Control	0.13	0.42	0.97	1.20
Diet 1	0.16	0.08	0.27	1.20
Diet 2	0.28	0.05	0.05	1.27
Diet 3	0.23	0.05	0.07	0.75
Diet 4	0.03	0.25	1.00	0.92
Diet 5	0.16	0.25	1.12	1.42

Table 10: Average daily length gain (ADL) (cm) of the spotted tilapia, *Pelmatolapia mariae* reared using artificial diets for 28 days

	Experimental period (days)			
Diets	7	14	21	28
Control	0.21	0.83	1.46	1.71
Diet 1	0.09	0.43	0.81	1.63
Diet 2	0.38	0.61	0.61	1.28
Diet 3	0.41	0.53	0.61	1.11
Diet 4	0.12	0.38	1.08	1.01
Diet 5	0.41	0.68	1.51	1.31

Table 11: Specific growth rate of the spotted tilapia, *Pelmatolapia mariae* reared using artificial diets for 28 days

	Experimental period (days)			
Diets	7	14	21	28
Control	0.08	0.08	0.17	0.20
Diet 1	0.08	0.02	0.05	0.20
Diet 2	0.11	0.01	0.01	0.21
Diet 3	0.10	0.01	0.02	0.14
Diet 4	0.07	0.06	0.18	0.16
Diet 5	0.08	0.05	0.19	0.23

Table 9 illustrates the average daily weight gain (ADG) of the spotted tilapia grown during the experiment. Fish cultured with Diet 5 showed the highest average daily weight gain followed by Diet 2. Fish fed with Diet 3 had a low average daily weight gain.

The average daily length gain (ADL) of the spotted tilapia observed during the experiment is exhibited in Table 10. After 28 days, control fish had the highest average daily length gain followed by fish fed with Diet 1 and 5. Fish reared with Diet 4 showed less average daily length gain.

Table 11 illustrates the specific growth rate of the spotted tilapia during the experiment. After 28 days, fish fed with Diet 5 showed the highest specific growth rate followed by Diet 2. The minimum specific growth rate was noticed in the fish fed with diet 3 after 28 days.

DISCUSSION

Fish are an excellent source of animal protein, providing essential nutrients for our bodies. However, it is important to note that the nutritional value of fish can vary depending on factors such as species, size, sexual conditions, feeding season and physical activity[15]. Unlike other animals, fish don't have a specific requirement for crude protein (CP). Instead, they need a combination of essential amino acids to thrive. Therefore, it is crucial to carefully formulate the dietary protein profile for fish. Factors like fish size, age, dietary protein source, energy content, water quality and culture conditions all play a role in determining the protein requirement of fish. The essential amino acids necessary for fish growth include arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. However, it is worth noting that the specific requirement for these essential amino acids can vary among different fish species. At the same time, insufficient feeding under high population densities can hinder growth and cause nutritional problems[16,17]. Therefore, it is essential to develop and produce artificial feeds that contain a well-balanced combination of essential nutrients. This ensures the prompt intensification of fish metabolic functions upon feeding.

Different compositions of diets were used in the current study to examine their impact on the growth of spotted tilapia. These diets included groundnut oil cake, rice bran, moringa leaves, cauliflower leaves, chicken intestine and chicken legs. The diets were prepared with varying amounts of protein, carbohydrate and lipid content. Diet 1, 2 and 5 were particularly rich in lipids, carbohydrates and proteins, respectively. Among the tested diets, the spotted tilapia exhibited the greatest total length and standard length when fed Diet 1, which consisted of groundnut oil cake, rice bran and chicken intestine. Following a 28 days experimental period, Diet 5, which comprised groundnut oil cake, rice bran, moringa leaves, cauliflower leaves, chicken intestine and chicken legs, resulted in the highest live weight, average daily weight gain, average daily length gain and specific growth rate. The present study utilized both plant-based protein sources (groundnut oil cake, rice bran, moringa leaves and cauliflower leaves) and animal-based protein sources (chicken intestine and chicken legs) for the formulation of the diets.

Fish meal, poultry byproduct meal, blood meal, hydrolyzed feather meal and meat are the most commonly used protein sources that enhance the protein content in fish[18]. Among these, fish meal is a traditional choice. Another group of alternative protein components used in fish diets are byproducts from the oil industry, such as oil cake and meal extracted from sunflower and peanut[19]. Additionally, plant protein sources like soybean meal, cotton seed meal and aquatic plants like *Lemna minor*, *Azolla pinnata*, *Hydrodictyon reticulatum*, *Potamogeton gramineus* and *Ceratophyllum demersum* can be utilized. These protein sources need to be consistently included in the diet to support fish growth and reproduction[20]. Diet 5, which contains all essential components, has a higher protein content. Plant products like cauliflower and moringa leaves can also increase the protein content in fish. Similarly, using rice bran as feed resulted in a higher protein content (28.87%) in *Labeo rohita*[21]. Protein is essential for the development of structural tissues, such as muscles and organs, as well as for follicle formation in embryos[22]. However, there was no significant increase in the growth of tilapia fed with a diet containing 35 to 45% protein[23]. Azolla, which contains essential nutrients, was used as a feed for *Tilapia mossambica*, leading to increased fish growth and protein production[24]. Spirulina, when used as a fish feed for tilapia, also increased the protein content in fish due to its faster growth rate compared to crops and microorganisms like yeast and bacteria[25].

Fish store carbohydrates as glycogen in their tissue and organs, such as muscle and liver, to use as an energy source. Compared to proteins, carbohydrates provide a larger amount of energy. Additionally, carbohydrates are a more cost-effective source of dietary energy compared to proteins and lipids[26]. However, fish generally have a low level of carbohydrates. Instead, amino acids and fatty acids that are already present in fish serve as precursors to supply glucose through gluconeogenesis. Therefore, most fish do not have a specific requirement for carbohydrates[27]. In terms of diet, Diet 3 (consisting of groundnut oil cake, rice bran and cauliflower leaves) and the control had higher carbohydrate content. The catfish species *Clarias batrachus* can utilize feed with varying levels of carbohydrates. Among these, a diet containing 15% carbohydrates resulted in better growth for *Clarias batrachus*, but its fry cannot tolerate a diet with about 20% carbohydrates[28].

Lipids serve as the primary source of energy and are crucial for the absorption of fat-soluble vitamins. They play a vital role in the structure and function of cell membranes and serve as precursors for steroid hormones. Fish lipids contain approximately 40% long-chain unsaturated fatty acids with 5-6 double bonds. Comparatively, the lipid content in fish is lower than that found in beef and chicken. Additionally, the lipid content is higher in control fish, specifically those fed with groundnut oil cake and rice bran. A fish diet with a high level of lipid content provides twice the amount of energy compared to protein and carbohydrates. However, relying solely on a single type of food is inadequate as it fails to supply all the necessary nutrients to the fish. Therefore, an artificial diet is utilized to ensure the fish receive all essential nutrients and this diet can be stored for extended periods without any changes in its composition[29].

In the current investigation, the growth of tilapia was monitored using artificial feed containing the necessary ingredients. Previous research on *Labeo rohita* has shown that fish growth is correlated with both overall length and weight gain when artificial feed is utilized[30]. When tilapia fry was continuously fed with artificial feed, there was an increase in the length of the fry during the final stages, but no significant growth was observed during the initial stage[31]. *Cirrhinus mrigala* exhibited higher growth when fish meal was used as a diet, whereas poor growth was observed when barley was used as a diet[32]. Similarly, the growth of *Labeo rohita* and *Cyprinus carpio* was enhanced by the use of an artificial diet[25]. The growth rate of *Poecilia sphenops* was found to be better when tapioca powder, beetroot, carrot and spirulina were included in the fish diet. Additionally, fish meal had the highest protein and fat content compared to tapioca flour[24]. Rice bran, which has a higher fiber content, was found to enhance fish growth. Spinach was also used as a feed for fish to ensure overall fish health[23]. It is recommended to include a lower quantity of maize oil cake in the fish diet in order to achieve a higher body weight[32]. In the case of tilapia fry, when fed with artificial feeds, there was no increase in weight observed initially, with the weight only increasing at the final stage due to continuous feeding with artificial feeds[31].

The progress of artificial fish feed has the potential to significantly impact the environment. The production and disposal of this feed could lead to pollution and disturb the delicate balance of aquatic ecosystems. Furthermore, the costs involved in developing and manufacturing artificial fish feed could potentially increase the overall expenses of fish farming, thereby affecting the market price of fish. Additionally, the use of artificial fish feed may have implications for the health and nutrition of farmed fish. Insufficient nutrient supply in the feed could result in health issues and undermine the overall quality of the fish harvest.

By incorporating artificial fish feed, the yield of farmed fish can be significantly improved, ensuring a consistent and regulated supply of nourishment. This innovation plays a vital role in addressing the increasing demand for fish while reducing the reliance on capturing fish from the wild, thus promoting sustainable fish farming practices. Through the customization of artificial fish feed, it becomes feasible to meet the specific nutritional needs of different fish species, thereby facilitating their enhanced growth and development.

Extensive research, like the present study, is indispensable to overcome the implications prior to the development of artificial fish feed. The research should focus on understanding the nutritional requirements of diverse fish species and the potential environmental consequences associated with the feed. Implementing stringent quality control measures throughout the production process is vital to ensure that the feed meets the essential nutritional criteria and is free from any harmful substances. Collaborating with fish farmers provides valuable insights into the specific challenges and needs of fish farming, which in turn facilitates the development of cost effective artificial fish feed that is both efficient in fish farming and sustainable for aquatic ecosystem.

CONCLUSION

In aquaculture, the preparation of artificial fish feed holds immense importance as it involves a meticulous selection of ingredients, precise formulation and suitable processing techniques to fulfill the nutritional requirements of the fish. The adoption of artificial feed has significantly contributed to the progress and expansion of the aquaculture industry, offering a cost-effective and efficient solution to feed a large population of fish. However, it is crucial to acknowledge that the quality of the feed plays a pivotal role in ensuring the well-being and growth of the fish. Therefore, continuous research and enhancement in the preparation of artificial fish feed are indispensable to cater to the changing nutritional needs of different fish species and promote sustainable aquaculture practices.

SIGNIFICANCE STATEMENT

The present work on preparation of artificial fish feed can be beneficial in the field of aquaculture for a better understanding of the influence of feed nutritional components on the growth of the fish. This study will pave the way for the researchers to uncover the critical areas of influence of artificial fish feed on the growth of aquatic organisms such as fish that many researchers have not explored. Thus a new theory on obtaining the desired marketable size of fish through artificial fish feed may be arrived at.

ACKNOWLEDGMENT

The authors thank the authorities of The American College, Madurai, Tamil Nadu- 625002, India for the facilities and encouragement.

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