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Effects of Fleshfly Maggots as an Alternative Meal for Red Tilapia, *Oreochromis niloticus* (Cichilidae)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Food is important for all organisms because it provides the energy required by a person for proper physical and mental functioning. Fish provides the best nutrients that help our body build and repair. This study was to evaluate the effectiveness of replacing fish meals for production with high-quality culture fish that is less costly. This study was conducted from January 2024 to March 2024. The red Nile tilapia, *Oreochromis niloticus* juvenile, is a member of the Cichlidae family. They were collected from the Fisheries Department's Neyyar dam at Trivandrum in Kerala. Third-instar larvae flesh flies are prepared by drying and pulverizing into powder form. Five groups of fries were maintained. Group 1 was fed on the usual fish meal. Group 2 was reared exclusively on the maggot meal made from the maggot reared on plant waste (MM 1). Group 3 fry were reared on maggot meal prepared

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from maggot reared or animal waste (MM 2), Group 4 fry were reared on mixed maggot meal prepared from plant waste (MM 1) with usual fish meal, and Group 5 fry were reared on maggot meal prepared from maggot reared on animal waste (MM 2) with usual fish meal. We were finally determined that Diet 5 (MM 2 + Usual Fish Meal) is more effective than other diets. The growth performance consists of the initial body weight being 0.12±0.12 and the final body weight being 4.57± 1.45, respectively. In the case of usual fish meal (Diet 1), it showed a lower growth rate (0.18±0.11) than other diets and finally attained 1.11±0.19 g. It therefore concluded that the maggot meal can be a good supplementary food with high nutrient values, which proved that the growth performance of *O. niloticus*

Keywords: Maggots; Fishmeal; growth performance; animal waste; dietary protein; nutrition.

1. INTRODUCTION

Our body needs certain specific nutrients for proper growth and development. We cannot get these nutrients by eating any type of food. We should have a properly balanced diet, which we should maintain according to our body requirements. There are different essential nutrients for the proper growth, development, and functioning of our body. They contain mostly proteins, vitamins, fats, minerals, and water. Each of these nutrients is important to our body, and they cannot be skipped or ignored because all these nutrients impart biomolecules for the proper functioning of our body. Fish is an easily attainable source of low-fat, high-quality protein. It helps lower blood pressure and reduces the risk of a heart attack or stroke. Tilapia, Oreochromis sp., is a popular food fish and is in great demand globally. Global tilapia production reached 3.2 million tons in 2010, and the demand for tilapia is still growing, especially in the United States, the largest single market for tilapia [1]. Selective breeding programs and genetic improvement technology have also been implemented to enhance the production of tilapia [2,3]. The global supply of fishmeal has dwindled due to overexploitation of the natural fishery stock. With the predicted continuous growth of the aquaculture industry [4], the demand for fishmeal will continue to increase, causing its price to soar. An estimated one-third of wild caught fish is used to produce fishmeal for aquafeed [5]. The poultry and swine industry are the largest fishmeal consumer [6], but the protein requirement for aquafeed is much higher than for livestock feed. The rapid growth of the aquaculture industry has changed fish capture patterns from large piscivorous fishes to smaller invertebrates and planktivorous fishes, but this has not alleviated the pressure on wild fisheries stocks [7]. This clearly presents a threat to marine ecosystems as well as a constraint to the long-term growth of the aquaculture industry itself. From a commercial perspective, fish is an important food source for many groups of people. Also, they are one of the most common pets because they are relatively easy to care for. [8] indicated that maggot meal could be used as an alternative to fishmeal in poultry feed. [9] studied the effect of substitution of fish meal (*Hermetia illucens*) on the relative length of digestive tract histomorphology of small intestines and the percentage of carcass parts in native chicken. Flesh flies (Diptera: Sacrophagidae) are closely associated with mammals, as these flies depend on liver or dead tissues to complete their life cycle. Commonly used in laboratories to study gene expression, diapause, and physiological processes. It has a significant impact in other areas. The larvae (maggots) of the flies feed on dead animal tissue, and such larvae are beneficial in nature as decomposers of dead animal carcasses. This is the species of fly that is most widely observed in organic waste recycling and in the biodegradation of multiple wastes such as food, restaurant waste, meat processing waste, and agricultural waste. Moreover, bioconversion of waste with flesh fly larvae as suitable nutritional supplement can serve as replacement for fish meal and other protein sources used in poultry nutrition and natural food sources for many animals. The metamorphosis of flies controls the rate of body composition, and adult flies develop from the maggots. There are various structural changes that occur during the four stages of the lifecycle of the insects—the eggs, larva, pupa, and adult stage. Several factors directly or indirectly impact the age and development of maggots, such as temperature, season, species, toxicology, and death scenario. The favorable conditions of the environment lead to a fast decomposition, whereas unfavorable circumstances result in a slow decomposition rate due to the gradual rate of maggots' growth and development. This study evaluates the potential of flesh fly maggots as an alternative dietary protein source for red tilapia by substituting flesh fly maggot meal with fishmeal in experimental diets and assessing the growth of the fish over time.

2. MATERIALS AND METHODS

Collection of specimens: Fresh beef liver and vegetable waste were the mediums for collecting flesh fly maggots. These were kept separately in the laboratory at 25°C–30°C. The adult female flesh flies larviposited on the decomposing meat and vegetable waste. Flesh fly maggots fed for three or four days and developed into the third instar, which was approximately 17 mm long. The third instar larvae were collected for meal preparation.

Flesh fly Maggot Meal (MM) preparation: The third instar larvae that were collected were killed with hot water, oven dried at 100° for 12 hours before being grinding/pulverizing into fine powder and sieved. The powdered meal was stored in bottles labelled for different diet groups, like Usual fish meal: Diet 1, Plant waste (MM 1): Diet 2, Animal waste (MM 2): Diet 3, MM 1 + Usual fish meal: Diet 4, MM 2 + Usual fish meal: Diet 5.

Collection of red Nile tilapia: Fourteen days old, the red Nile tilapia, *Oreochromis niloticus* a member of the Cichlidae family, was collected from the Fisheries Department Neyyar dam at Trivandrum, Kerala. Thirty selected fish were kept in five tanks, with each tank containing six fish.

Feeding trial and experiment: For this study, fourteen-day old red tilapia fry of the same brood were selected. Five groups of each fry were maintained. Group 1 was fed the usual fish meal. Group 2 was reared exclusively on the maggot meal made from the maggot reared on plant waste (MM 1). Group 3 fry were reared on maggot meal made from animal waste (MM 2), Group 4 fry were reared on maggot meal prepared from plant waste (MM 1) with usual fish meal, and Group 5 fry were reared on maggot meal prepared from maggot reared on animal waste (MM 2) along with usual fish meal in the ratio 1:1.Group 3 fry were reared on maggot meal made from animal waste (MM 2), Group 4 fry were reared on maggot meal prepared from plant waste (MM 1) with usual fish meal, and Group 5 fry were reared on maggot meal prepared from maggot reared on animal waste (MM 2) along with usual fish meal in the ratio 1:1. Five tanks were set up for each experimental diet; fry were kept in a natural photoperiod (12:12). The fry was fed twice daily for 90 days at a daily feeding rate of 0.13 g to 0.6 g. Every five days, the weight of the fish was recorded in grammes before and after feeding, and the amount of food provided was also weighed in grams. The conversion ratio were calculated. At the end of the feeding trial, fish were fasted for 24 hours before the final body weight was recorded. The specific growth rate (SGR), feed conversion ratio (FCR) was calculated as follows: SGR = (final body weight-initial body weight)/number of days x 100.

Fig. 1. Third instars larvae

Fig. 2. Heat killed maggot

Fig. 3. Oven dried maggot

Fig. 4. Powdered maggot meal

3. RESULTS AND DISCUSSION

Table 1. Effect of different diet on growth performance (Live weight in g) in 14-104 days

Age of fish On days	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
14 days	0.18 ± 0.11	0.16±0.03	0.17 ±0.12	0.23±0.04	0.12 ±0.12
19 days	0.24±0.08	0.19±0.04	0.19±0.02	0.29±0.06	0.32±0.07
24 days	0.32±0.05	0.26±0.53	0.26±0.03	0.36±0.04	0.39±0.04
29days	0.36 ±0.06	0.35±0.04	0.30±0.03	0.38±0.05	0.47±0.04
34 days	0.4±0.06	0.42±0.07	0.44±0.07	0.39±0.07	0.62±0.11
39 days	0.43±0.07	0.54±0.11	0.56±0.07	0.45±0.08	0.72±0.10
44 days	0.45±0.06	0.55±0.11	0.65±0.07	0.47±0.09	0.78±0.35
49 days	0.53±0.06	0.70±0.17	0.81±0.17	0.72±0.27	1.12±0.28
54 days	0.66±0.06	0.79±0.17	1.06±0.29	1.06±0.33	1.3±0.21
59 days	0.80±0.08	1.07±0.13	1.41±0.15	1.21±0.15	1.68±0.44
64 days	0.84±0.11	1.22 ±0.23	1.51 ±0.19	1.25±0.8	2.03±0.68
69 days	0.91 ±0.19	1.27 ±0.26	1.61 ±0.19	1.28±0.07	2.21±0.81
74 days	0.95 ±0.23	1.36 ±0.31	1.68 ±0.16	1.31±0.06	2.43±1.10
79 days	0.96 ±0.25	1.45 ±0.36	1.75 ±0.13	1.34 ±0.05	2.50±0.96
84 days	0.99 ±0.20	1.38 ±0.11	1.85 ±0.30	1.36±0.09	2.93±0.97
89 days	1.01 ±0.20	1.39 ±0.11	1.94 ±0.33	1.38±0.33	3.09±1.01
94 days	1.03 ±0.20	1.24 ±0.47	2.01 ±0.35	1.41±0.09	3.49±0.89
99 days	1.07 ±0.20	1.42 ±0.11	2.07 ±0.38	1.43±0.10	3.49±0.89
104 days	1.11 ±0.19	1.44 ±0.11	2.13 ±0.39	1.46±0.10	4.57±1.45

3.1 Growth Performance of Red Tilapia In 14-104days old (MM2+Usual fish meal)

Fig. 5. (14 days old fish)

Fig. 6. (104 days old fish)

Table 2. Ascertaining of growth performance

Experimental diets	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Initial body weight (g)	0.18±0.11	0.16±0.03	0.17±0.12	0.23±0.04	0.12±0.12
Final body weight(g)	1.11±0.19	1.44±0.11	2.13±0.39	1.46±0.10	4.57±1.45
weight gain	0.93 ±0.08	1.28± 0.08	1.96± 0.27	1.23 ±0.06	4.45± 1.33
Length increment	2.22± 0.34	3.38 ±0.01	3.6 ±0.6	2.35± 0.01	4.33± 0.31
PWG	516± 72.27	800 ± 266.67	1152.9± 225	534.78± 150	3708 ± 1108
SGR (% day^{-1})	1.03± 0.08	1.23 ±0.08	2.17± 0.3	1.18 ±0.06	4.27± 1.47
Survival (%)	100	100	100	100	100

*Weight gain: Final bodyweight (W_x) – Initial body weight (W_y)
*Length increment: Final length (L_x) – initial length (L_Y)
*Percentage weight gain (PWG)
*SGR (specific growth rate) = (Final body weight-Initial body weight)/number of days) x100
* Survival (%) = $L_1 / L_2 \times 100$ (L_1 = Number of the fish at the end of experiment , L_2 = Number of fish at the end of experiment)

Table 3. Food utilization indices *O. niloticus* comparison between fed usual fishmeal and maggot meal from animal waste

Food utilization indices	Tending A (Usual fish meal) - Diet 1	Tending B (Maggot meal from animal waste) – Diet 3
Weight gain(g)	0.93 ±0.08	1.96± 0.27
Food consumed(g)	7.98±0.25	7.98±0.25
SGR	1.03± 0.08	2.17± 0.3
FCR	7.00 ± 1.20	3.74± 0.52

*Weight gain: Final bodyweight (W_x) – Initial body weight (W_y)
*Food consumed: Food consumed in each groups/ Number of days (Here total food consumed in all groups = 39.9g)
*SGR (specific growth rate) = (Final body weight-Initial body weight)/number of days) x100
*FCR (Feed conversion ratio) =Total feed intake(g) / (Final body weight –Initial body weight (g)

3.2 Usual fish Meal: Diet 1

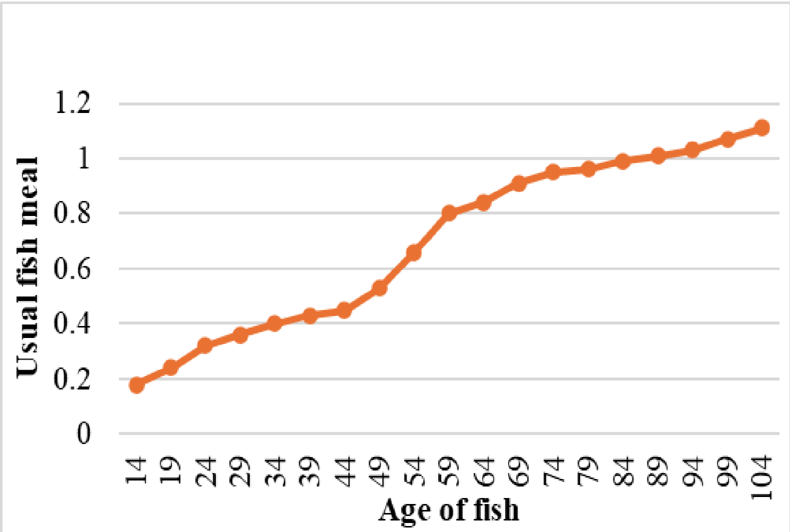
The growth performance of *O. niloticus* with the use of dry maggot was evaluated for 90 days. The initial weight of *O. niloticus* using usual fish meal was 0.18±0.11 g. After the first month, the growth rate slowly increased to 0.43±0.07 g.The total weight of 104-day-old fish was 1.11±0.29 g and the length was 4.28±0.42 cm, with a total feed of 7.98±0.25 g of usual food meal.

3.3 Maggot Meal 2 (MM 2): Diet 2

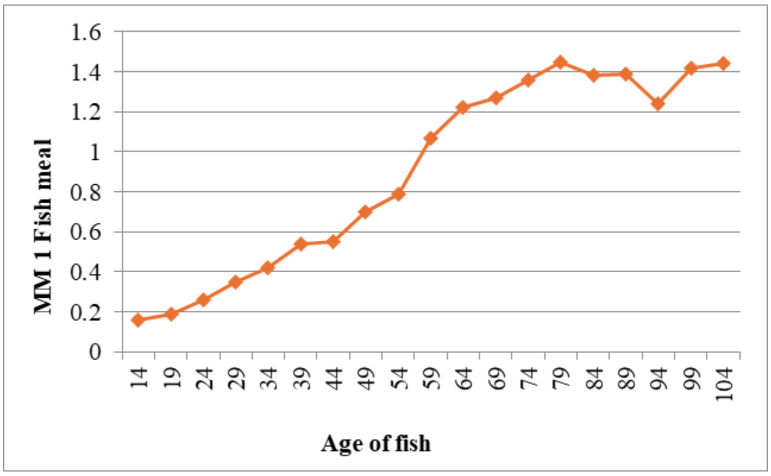
The maggots taken from plant or vegetable waste were used for maggot preparation; the initial weight of *O. niloticus* was 0.16±0.033 g and the length were 2.13±0.33 cm. The growth performance evaluated after one month was 0.54 ± 0.11 g of weight and a length of 3.25 ± 0.24 cm. with 26 g of dry powdered maggot meal. The evaluation was completed after 90 days, and the result of the weight of *O. niloticus was* 1.44± 0.11 g. and 5.51±0.42 cm, with 7.98±0.25 g total utilised foods.

3.4 Maggot Meal 2 (MM 2): Diet 3

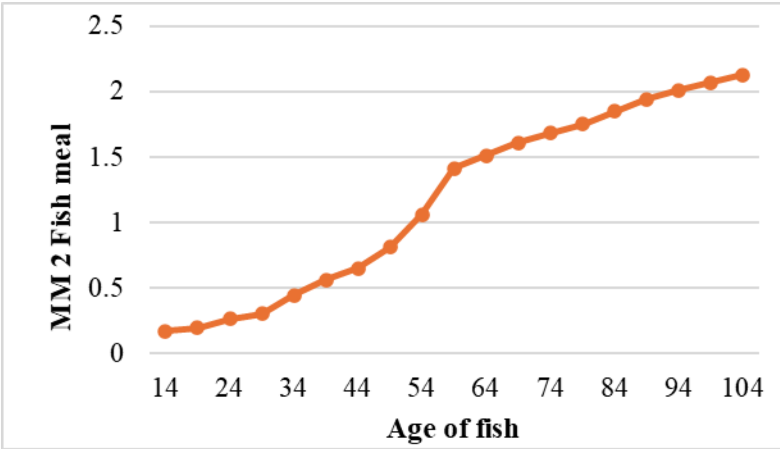
This was the study done using animal waste, i.e., meat waste. The *O. niloticus* initial weight was 0.17±0.02 g, and the length was 2.13±0.33 cm. After starting to use the maggot meal diet, its weight increased to 0.56±0.07 g and its length to 3.1±0.12 cm within a month. As a result of using this maggot meal again for 90 days, the weight of *O. niloticus* increased to 2.13±0.39g and the length to 5.43±0.85cm, respectively.



Graph 1. Graph showing Usual fish Meal (Diet 1)



Graph 2. Graph showing maggot Meal 2 (Diet 2)



Graph 3. Graph showing maggot Meal 3 (Diet 3)

3.5 MM 1 + Usual Fish Meal, Diet 4

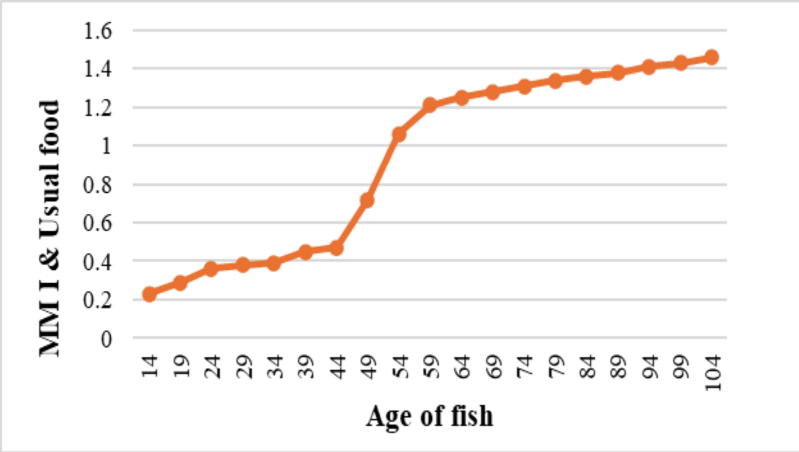
A mixed diet of maggot meal 1 and the usual fish meal was used here. The *O. niloticus* initial weight and length were 0.23±0.04 g and 2.13±0.33 cm (Tables 1 and 3), respectively, but the result after one month is 0.39±0.07 g and 3.46±0.19 cm. Again, after 90 days, we got a good result, which means weight and length increased to 1.46±0.10 g and 2.13±0.33 cm, respectively.

3.6 MM 2 + Usual Fish Meal, Diet 5

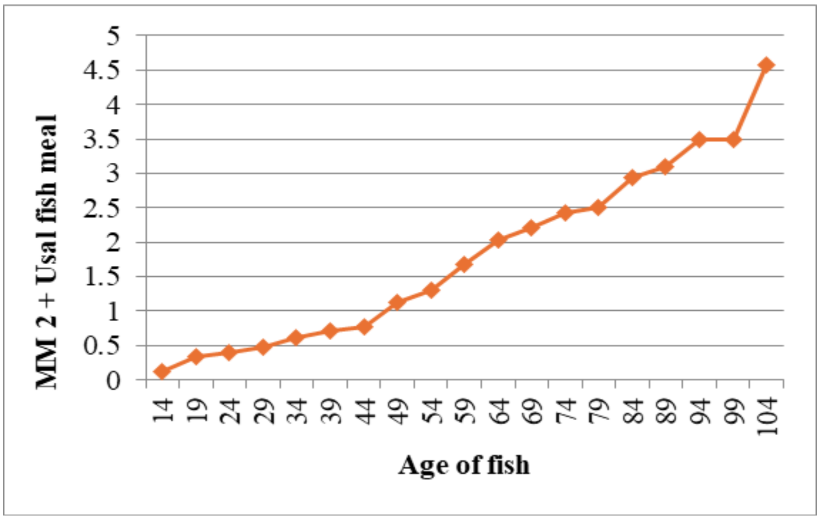
The result showed that the weight and length performance were higher, i.e., the initial weight and length were, respectively, 0.12±0.02 g and 1.93±0.36 cm. Then the changes were seen after a month, which are 0.72±0·10 g and 3.38±0.23 cm. After 90 days, the growth rate gradually increased with the use of supplemented maggot meal with usual fish meal. Finally, it reached a total weight of 4.57 ± 1.45 g and a length of 6.26 ± 0.73 cm.

3.7 Growth and Feed Efficiency of Red Tilapia Fry

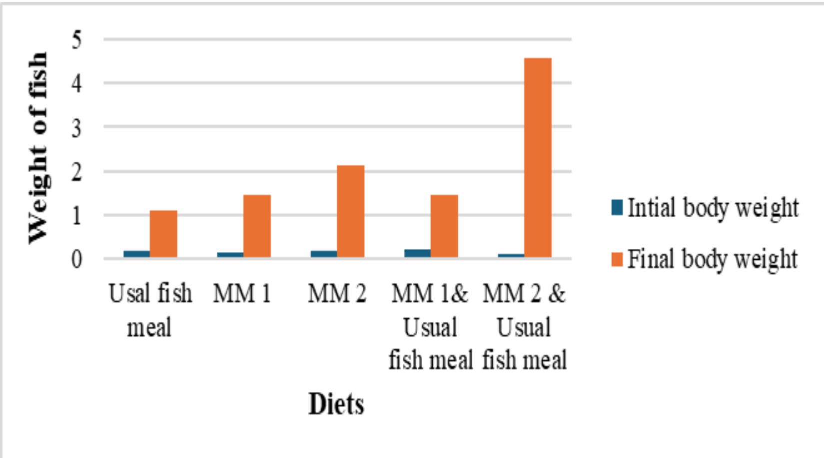
The final body weight gain and SGR, measured at the end of the 90-day trial, showed a direct relationship with the percentage of maggot meal in the experimental diets (Tables 1,2). The growth performance of *O. niloticus* (4.57±1.45) in D 5 (MM 2 + usual fish meal) was higher than other groups (Table 2). Fish fed on Diet 5 also showed the best (lowest) FCR significance (Tables 2,3) as well as the highest SGR (4.27± 1.47). Fish fed with usual food showed the lowest growth (SGR 1.03± 0.08)) with a feed conversion ratio (FCR 7.00± 1.20), which was very high compared to other groups.



Graph 4. Graph showing Usual Fish Meal (Diet 4)



Graph 5. Graph showing Usual Fish Meal (Diet 5)



Graph 6. Growth and feed efficiency of red tilapia fry

Fish feed formulations contain a lot of different ingredients to incorporate all the necessary nutritional requirements that farmed fish require to develop and grow. Such formulations need to supply the nutritional requirements to the farmed fish so that it can achieve normal physiological functioning. In marine origin, such feeds contain usually fishmeal and fish oil. 60% of current fish meal production and about 80% of fish oil production are used in the production of fish meal. Thus, the growth of aquaculture could be greatly restrained in the future due to shortages of fish meal and fish oil. To overcome the dependency on such exhaustible resources and prevent the loss of marine biodiversity from happening, feed manufacturers are searching for more sustainable ingredients to develop an alternate source to provide the dietary nutrition of farmed fish through artificial feed formulations. According to Oso et al. [10], aquaculture needs to be supported by the development of new species-specific diet formulations as it expands to satisfy the increasing demands for affordable, safe, and high-quality fish and seafood products. In this study, an effort was made to find whether a meal made from maggots of flesh flies could be used as an alternate feed to the usual fish feed provided. Maggots were sourced from two forms of waste: plant-based and animal-based. Five types of experimental diets were utilized to feed the tilapia placed in five separate glass tanks. It was observed that the maggot meal sourced from animal waste along with the usual fish meal provided positive results compared to the other four diets. This was followed by the diet that contained maggot meal sourced from plant waste added along with the usual fish meal, followed by the diet containing only maggot meal sourced from animal waste, followed by the diet containing maggot meal sourced from plant waste, and finally the diet that contained the usual fish meal. But when the length-weight relationship was assessed along with conditioned factor K, the growth of the fish was found to be allometric rather than isometric in nature. There have been numerous experiments on the use of maggots in the diets of African catfish, *Clarias gariepinus*. The maggot meal the maggot meal should be limited additionally. 25-30% performance may decrease when higher addition rates are used [11]. Maggot meal has been reported to be a possible alternative to expensive protein sources [12, 13, 14]. It is also produced from waste, which otherwise would constitute an environmental nuisance. This production system thus serves the dual purpose of providing a nutrient-rich resource as well as a source of waste transformation and reduction [2]. There is no commercialized production system developed [4], maybe because its utility and value as a feed ingredient have not been evaluated, and previous work on maggot meal was done only under experimental conditions. In this study, it can be observed that the diets that were added along with the fish meal were preferred over the diets containing maggot meal alone. This could be either because of the taste, texture, and smell of the maggot meal; the maggot meal would not have been a preferred food or because the feed was more palatable when the maggot meal was added along with the usual fish meal, hence the preference. Moreover, allometric growth was observed, which defies Cube's law. This might be because in formulated fish feeds to ensure that the dietary nutrients are ingested, digested, absorbed, and transported to the cells, an increasing number of non-nutritive feed additives are used. This is to ensure that maximum benefit is attained from the alternate artificial food that is provided to the farmed fish. In the diets provided in this experiment, no such additives were added except when the maggot meal was added along with the usual fish meal, which might contain such additives, which might explain the improved development in the fish maintained on the said diets. When rearing farmed fish for human consumption, it should be ensured that the diets that are provided to such farmed fish do not cause any adverse effects when consumed. Maggot meal as an alternative feed would be a safe bet due to its advantage of being reared from plant and animal waste and thus a boon to the environment, but it requires more studies to understand how the fish will be able to process the food and if it is obtaining its dietary requirements through the maggot meal alone or should the maggot meal be supplemented to increase the nutritional output. More studies are required to categories maggot meal as a substantial alternate to fish meal.

4. CONCLUSION

A sustainable aquaculture venture demands good-quality food and intensive feeding. In some cases, especially in developing countries, more than 60% of the operating cost goes into fish feeding because fish meal, a major animal protein source, is scarce and expensive. Therefore, to reduce the costs of fish production and optimize profits, there is a need for a cheaper but nutritionally effective alternative protein source to fish meal. In these studies, it is observed that maggot meal has potential as a good source of animal protein in fish nutrition. The use of dry maggots in feeding fish is often practiced. However, the carcass and flesh yield of fish produced is better when the maggots are processed into meal. In this project, it was observed that maggot meal can be used to supplement the fish meal in the diets of Nile tilapia. This offers a good opportunity for the development of low-cost aqua feeds, particularly in developing countries where fish meal is imported, very expensive, and not readily available. Large quantities of flesh fly larvae can be produced from animal waste and agricultural waste within a short period of time. This could be used to supplement fish meal with maggot meal in tilapia feed, which could directly reduce production costs. Further research is needed to improve and define good food production and to determine the potential of maggot meal as a feed ingredient for other commercially important fish species.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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