



# Effect of Insect Meals on the Growth Efficiency, Survival and Total Carotenoid Content of an Ornamental Fish *Xiphophorus maculatus* (Gunther, 1866)

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## Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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## ABSTRACT

To evaluate the effects of three non-conventional insects (cricket, grasshopper and mealworm) and commercial diet (control) on growth, survival and total carotenoid content of ornamental fish, platy (*Xiphophorus maculatus*), a feeding trial was conducted in Zoology laboratory, Vidyasagar College, West Bengal, India, between November 2021 and May 2022. A total of 250 platy juveniles ( $0.04 \pm 0.002$  gm) were stocked in 12 glass aquariums with 20 fishes for each experimental feed set. Each experimental diet was made per triplicate. The growth efficiency parameters of platy fish in terms of weight gain percentage, specific growth rate (SGR), feed conversion ratio (FCR) were measured at the end of the study period. Protein content in percent is significantly higher in mealworm ( $46 \pm 0.58$ ) and then in grasshopper ( $42.50 \pm 0.29$ ). Final weight of fishes was significantly higher in mealworm fed sets ( $2.134 \text{ gm} \pm 0.008$ ) and lower in commercial meal fed sets ( $0.827 \text{ gm} \pm 0.003$ ). The lowest FCR was found in commercial diet ( $0.458 \pm 0.002$ ) and best FCR

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values was found in cricket diet ( $0.280\pm 0.001$ ). Higher value of SGR was obtained in mealworm fed sets ( $2.209\pm 0.002$ ) and lower SGR was in commercial diet ( $1.683\pm 0.002$ ). Mean survival percentage was 90% in mealworm diet and lowest survival value was 55% at commercial diet. Carotenoid content in fish body was significantly higher in mealworm diet ( $9.23\mu\text{g/g}\pm 0.071$ ), while lowest was observed in commercial diet ( $0.47\mu\text{g/g}\pm 0.001$ ). Present study shows that insect diets were better than commercial diet, but mealworm diet was better to increase survival and carotenoid content in *X. maculatus*.

**Keywords:** Carotenoid; cricket; grasshopper; growth; mealworm.

## 1. INTRODUCTION

In recent times, aquarium fish culture is a small-scale fish farming with low investment and high profit yield due to their always ever-increasing demand in the worldwide export trade. In India there is a sharp rise in international trade of ornamental fish with eight percent annual growth rate [1]. To meet their high requirement and to get the profit, ornamental fish farmers' constant effort is to enhance the fish skin colouration as it determines their market value and their commercial acceptability. Therefore, there is an urgent need of investigation for exploring a low-cost, easily available, alternative non-conventional protein source with natural carotenoid for the ornamental fishes. Platy (*Xiphophorus maculatus*) is a freshwater brilliantly coloured ornamental fish because of their chromatophores and colour pigment containing cells which are found in skin of platy [2]. Different shades of red and orange (carotenoid), yellow (xanthophylls), and brown of platy are the results from the utilization of carotenoids as principal resource of fish skin pigmentation [3,4] but they cannot be synthesized by fish *de novo* [5] and then they need taken through enriched diets with carotenoids, then absorbed and sometimes convert to other carotenoids, and later taken into different tissues and are deposited in their skin [6].

In nature fish obtain their required carotenoid by consuming carotenoid rich aquatic plants, weeds, algae and some arthropods [7,8,9,10,11,12,13]. Several works have been documented that fish pigmentation can be enhanced by adding different processing wastes and plant sources [14,15]. Hence, colour supplementing diets should include additional natural or synthetic carotenoids to enrich the colour of ornamental fish. In that, required natural carotenoid sources and such sources should be easily available and have low cost or nearly costless.

In this scenario, insects are an alternative protein source that are easily available, could be reared

or harvested. Insects have high nutritional value and consumed as food in the different parts of the world. But insects as food is not practiced in many developing countries where this huge insect protein biomass are wasted. Aquatic insects are natural diets for omnivorous and carnivorous fishes [16,17]. Hence, the insect biomass could serve as an alternative feed for ornamental fish culture and a cost effective non-conventional feed for fish. Very recently, insects have started to play a key role in fish culture as alternative protein sources [18]. Among insects, grasshoppers, crickets and mealworms are easy to breed and rear [19,20,21], and have a valuable protein profile [22,23,24]. Since, there is no works on ornamental fish using insects as feed to find whether insects have any role in enhancing their growth and skin pigmentation.

Based on these aspects, the present study was an attempt to determine the potentiality of grasshoppers, crickets and mealworms as fish feed and to evaluate their suitability based on growth, survival and colouration of *X. maculatus*.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site and Experimental Fish

The experiment was conducted and maintained in the laboratory of Department of Zoology, Vidyasagar College, West Bengal, India. For the experiment (six months period) 250 juveniles (average weight 0.04 gm and average length 0.6 cm) were acclimatized in a glass aquarium (36"x12"x12") for 10 days in laboratory condition and fed with commercial diet. After this period, fishes were randomly collected and four experimental sets in glass aquariums (18"x12"x12") were prepared with three replicates following a completely randomized design (CRD). In each set 20 fishes were stocked. The fishes were fed twice daily in the morning and evening at the rate of 5% of body weight per day.

Twice in a day, the water of the experimental glass aquariums was siphoned off to remove the extra feed particles. Water exchange was done twice a week to remove metabolic wastes.

## 2.2 Experimental Diet

Grasshoppers and crickets were collected from nearby grassland field of Vidyasagar college, Kolkata, India, by sweeping method using insect net. Mealworms were purchased from local market. These insects were freeze killed and then they were oven-dried at 60°C for 72 hours. The dried specimens were manually micronized and kept in airtight zipper plastic bags until further use in feeding trial and analysis.

### 2.2.1 Proximate composition analysis

Proximate analysis of experimental meals was carried out to obtain crude protein, fat, fibre and moisture contents using the method of AOAC [25].

## 2.3 Growth Study

Final weight and length of fishes were recorded at the end of the experimental period of 6 months. The growth efficiency of platy fish was evaluated in terms of specific growth rate (SGR), total food consumption and feed conversion ratio (FCR).

## 2.4 Estimation of Carotenoid

Carotenoid content of experimental feed samples were estimated by Cyanotech [26] method. At the end of the feeding trial, coloured region of skin and tissue of fishes from four experimental sets were collected to measure the total carotenoid content following the method of Tiewsoh et al. [27].

## 2.5 Water Quality Analysis

Physical and chemical parameters of water like temperature, dissolved oxygen, pH, free carbon dioxide, hardness, alkalinity, and TDS of experimental aquariums were analyzed twice a week using standard methods [28].

## 2.6 Statistical Analysis

Data were presented in tables and figures as mean  $\pm$  SE. One way analysis of variance (ANOVA) was done for all the data and then

Duncan's multiple range tests (DMRT) were carried out for each case to separate the mean values according to significance.

## 3. RESULTS AND DISCUSSION

### 3.1 Water Quality Parameters

Physical and chemical water quality parameters of different experimental aquarium sets were shown in Table 1.

Throughout the experimental period of six months, the range of values of physico-chemical parameters of water in the experimental aquariums were noted in Table 1. Though the ground water of the experimental area, used in experimental sets, having higher water hardness and TDS, did not show any adverse effect on the fishes during the acclimatization period. This finding was asserted by earlier studies, where demonstrated that ornamental fishes have high adaptability and are capable of surviving in water with a wide range of hardness and TDS [29,30]. As all the experimental aquariums contained the same ground water, therefore all the experimental fishes encountered the same range of water hardness and TDS. Hence, it could be safely said that there was no such isolated influential effect of this high range of water hardness and TDS on growth efficiency and survival rate of platy fish.

### 3.2 Nutrient Composition of Experimental Meals

The proximate nutritional composition of commercial feed, grasshopper meal, cricket meal and mealworms diets were listed in Table 2.

### 3.3 Growth Efficiency

The growth efficiency parameters of the platy fish at the end of the experiment are shown in Table 3. The initial length of platy fish varied from 0.55 cm to 0.65 cm. After six months, the result of final length showed significantly higher value in mealworm meal fed set followed by grasshopper meal fed set and significantly lower value was found in commercial meal fed set. The initial weight of platy fish ranged from 0.037 gm to 0.043 gm. At the end of the experiment, the best live final weight was recorded from mealworm meal fed set followed by grasshopper meal fed set and poorest value was noticed in commercial meal fed set. Similarly, significantly

highest weight gain is noted in mealworm fed set and lowest in commercial diet fed set. In case of the result of specific growth rate (SGR) in percent, again significantly highest value was detected in mealworm fed set and second highest in grasshopper meal fed set whereas lowest value was obtained from commercial meal fed set. Total food consumption was significantly higher in mealworm fed set and lower in commercial meal fed set. Platy fishes from commercial meal fed set showed significantly higher value for feed conversion ratio (FCR) whereas lower value was obtained from cricket meal fed set followed by grasshopper meal fed set.

In the current study, it was noticed that all the three chosen insect meal played a positive role in improving weight gain, SGR (%) and FCR of *X. maculatus*. Highest weight gain and specific growth rate were obtained in mealworm meal which contain 46% protein followed by grasshopper containing 42.50% protein and then in cricket meal with 37.67% protein and lowest in commercial meal as diet containing least percentage of protein (33.83%). This finding is comparable with the relevant works conducted by Chong et al. (2004) [31] on *Xiphophorus helleri* where they proved that higher weight gain and better SGR were obtained when the fish were fed with diets containing more than 40% protein.

In the present study, a varied range of growth rate were obtained in the four experimental meal fed sets, mainly due to variation in nutrient composition of their diet, amount of consumed food, and also on utilization of food energy. Here Platy fishes from mealworm meal fed set showed higher value for weight gain, total food consumption and SGR (%) and lower values for all these parameters were noted in commercial meal fed set. The results support the observation of Johnston et al. [32] and Sapkale et al. [33] where demonstrated that higher growth was obtained with the increased food consumption by *X. maculatus*. Higher consumption of diets by platy reflects higher weight gain and higher growth of selected fish rather than maintenance [34].

A significant weight gain increase and concurrent FCR decrease was observed in the mealworm meal fed fishes, followed by grasshopper meal and then cricket meal fed fishes which were more acceptable than commercial meals. According to Weisburger and Chung [35] the

improved weight gain and FCR is an indicator of improved utilization of nutrients. Results of the present study revealed that insects as fish feed significantly affect growth as well as FCR of platy fishes.

**Table 1. Physical and chemical water quality parameters of experimental aquarium sets during the experiment**

Parameter	Minimum	Maximum
Temperature (°C)	26	33
Dissolved Oxygen (ppm)	8.1	8.4
pH	7.2	7.4
Free Carbon dioxide (ppm)	1.45	2.16
Hardness (ppm)	590	660
Alkalinity (ppm)	320	336
TDS (ppm)	920	1085

### 3.4 Survival Percentage

Survival percentage was significantly higher in mealworm meal fed set (90%) and lower in commercial meal fed sets (55%) (Fig. 1). This result was supported by the fact that when fish obtained the diet with high nutritional value showed, in addition to higher growth efficiency and feed utilization, a positive impact on survival rate. The same opinion was reported by Sapkale et al. [33] for *X. maculatus* when provided optimum nutrition.

### 3.5 Carotenoid Content of Fish Meal and in Fish Skin and Tissue

The spectrophotometric analysis of pigment content of platy fish meals was estimated and the highest value was found in mealworm, followed by grasshopper and lowest in commercial meal (Fig. 2).

Among the four experimental meal sets, the concentration of carotenoid deposition in the body of platy fishes was significantly higher in mealworm diet fed experimental fish sets, whereas lowest value was reported in commercial diet fed fish sets (Fig. 3).

Carotenoid play an effective role in fish intermediary metabolism [36] which may responsible for enhancing nutrient metabolism that ultimately could improve growth of fish [37]. In the present study, significantly highest growth percentage reported in mealworm fed sets might be due to the amount of diet's natural carotenoid that may have growth promoting role. Vitamin A and some nutrients are formed in the carotenoid metabolism in fishes which act as growth promoter [11]. A similar type of results was noticed in some previous

findings in red sword tail [38], rainbow trout [39], goldfish [40] and in guppy fish [41] which indicate that amount of carotenoid content in fish feed linked to the growth enhancement of fishes.

Storebakken and No [42] and Torrissen et al. [43] reported that the absorption and deposition of carotenoid in platy fishes is steadily influenced by the nature of carotenoids, carotenoid concentration in diets and the size of fishes. In the present study, mealworm diets increased the carotenoid level in the tissue and skin of platy fishes, then fed with grasshopper meal followed by cricket meal. This observation clearly depicted that carotenoid deposition in fishes directly linked with dietary carotenoid content which ultimately increase colouration. Goldfish showed a similar trend of results when fed with various natural carotenoid sources like Spirulina [44], red yeast [45] and alfalfa [46].

The amount of carotenoid deposition in fish tissue and skin is species specific [47]. The

maximum level of carotenoid content in fish tissue and skin is definite which is attained by taking an optimum quantity of carotenoid through feed [48]. Over that quantity of carotenoid in feed did not show any increase in carotenoid deposition in fish tissue and skin [49].

It was found that several carotenoid source like blue green algae and spirulina and some plant sources like beet root [38], tomato and carrot [41] and paprika [50] as fish feed greatly influenced colour development in ornamental fishes. Still now, various natural carotenoid sources from plant origin have been successfully tried in ornamental fishes. However, the study on ornamental fishes with natural carotenoid sources from animal origin are very limited and hence, in the present investigation, nonconventional sustainable insect protein sources with favourable amount of carotenoid were tried as fish feed which showed not only significant effect in skin colouration but also on growth, FCR and survival percentage of platy fishes, *X. maculatus*.

**Table 2. Proximate nutritional composition of commercial feed, cricket meal, grasshopper meal and mealworms meal**

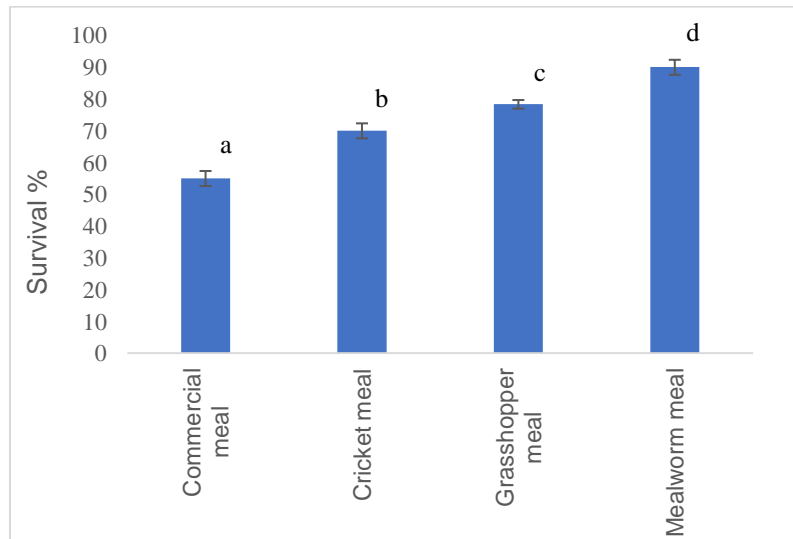
Nutritional composition (%)	Commercial meal	Cricket meal	Grasshopper meal	Mealworm meal
Crude Protein	33.83±0.44a	37.67±0.88b	42.50±0.29c	46.00±0.58d
Crude fat	3.60±0.31a	4.67±0.17b	4.57±0.30b	18.97±0.28c
Crude fibre	3.87±0.07b	2.90±0.60a	11.83±0.17d	6.47±0.15c
Moisture	11.33±0.67c	9.07±0.12a	11.33±0.20c	9.63±0.20b

\*Data are presented as mean ± SE. Within a row a, b, c, d indicates significant differences between mean values. (P=.001, DMRT)

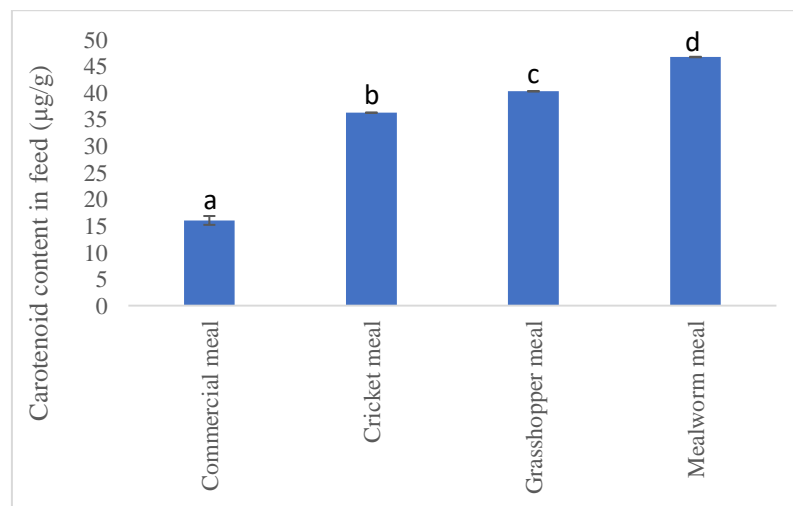
**Table 3. Growth parameters of platy fish, *X. maculatus* fed with different insect meals in six months feeding trial**

Growth parameters	Diets			
	Commercial meal	Cricket meal	Grasshopper meal	Mealworm meal
Initial length (cm)	0.60±0.029a	0.57±0.017a	0.58±0.017a	0.58±0.033a
Final length (cm)	3.500±0.000a	4.067±0.033b	4.933±0.067c	5.267±0.033d
Initial weight (gm)	0.04±0.002a	0.04±0.002a	0.04±0.002a	0.04±0.002a
Final weight (gm)	0.827±0.003a	1.346±0.003b	2.053±0.012c	2.134±0.008d
Weight gain (gm)	0.79±0.010a	1.29±0.014b	2.01±0.011c	2.09±0.014d
SGR (%)	1.683±0.002a	1.953±0.001b	2.188±0.003c	2.209±0.002d
Total food consumption (gm)	0.36±0.001a	0.37±0.001b	0.63±0.002c	0.68±0.001d
FCR	0.458±0.002d	0.280±0.001a	0.312±0.001b	0.325±0.001c

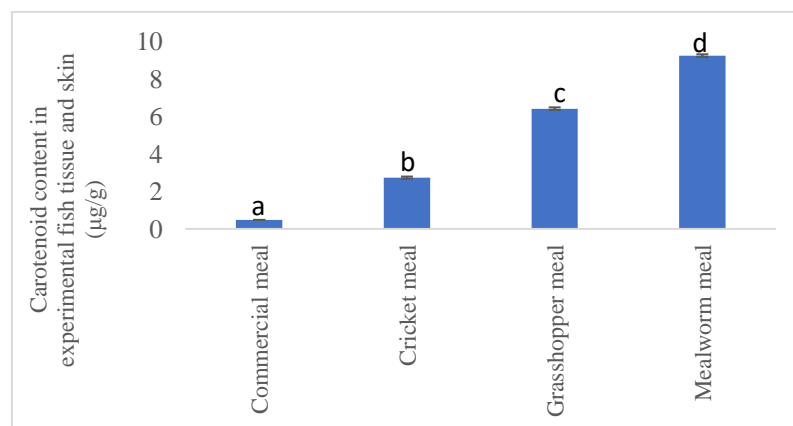
\*Values are mean ± SE. values with different letters are significantly different (P=.001) using DMRT.



**Fig. 1. Survival percent of *X. maculatus* fed with four experimental meals**  
Values are mean  $\pm$  SE. Bars with different letters are significantly different ( $P=0.001$ ) using DMRT



**Fig. 2. Carotenoid content (µg/g) in four experimental meals**  
\* Values are mean  $\pm$  SE. Bars with different letters are significantly different ( $P=0.001$ ) using DMRT



**Fig. 3. Carotenoid content (µg/g) in four experimental meal fed fish tissue and skin**  
Values are mean  $\pm$  SE. Bars with different letters are significantly different ( $P=0.001$ ) using DMRT

#### 4. CONCLUSION

To conclude, the recent study revealed that among the three insect meals, mealworm and then grasshopper meal increased the growth efficiency and feed utilization of platy fish. Moreover, enhanced skin colour was observed in mealworm fed fishes, followed by grasshopper fed sets. This result suggests that platy fish, *X. maculatus* has the potentiality to efficiently utilize the carotenoid of insect tissue and then to store in the fish skin and tissue and ultimately enhancing skin colouration. As synthetic carotenoids are very expensive, easily available insects with natural carotenoid such as mealworm and grasshopper would be the alternative cheap natural protein and carotenoid source as feed for the ornamental fish seller to obtain most profile value with these fishes.

#### COMPETING INTERESTS

Author has declared that no competing interests exist.

#### REFERENCES

1. Raja K, Aanand P, Padmavathy S, Sampathkumar JS. Present and future market trends of Indian ornamental fish sector. *Int J Fish Aquat Stud.* 2019;7(2): 06-15.
2. Jorjani M, Sharifroohani M, Mirhashemi RA, Enayat GT, Mirzaei MR, Tan SH. The effects of Marigold as natural carotenoids on scale chromatophores variations in blue gourami under different stocking densities. *J Surv Fish.* 2019;29-36.
3. Kaur R, Shah TK. Role of feed additives in pigmentation of ornamental fishes. *IntJ Fish Aquat Stud.* 2017;5(2):684-686.
4. Nakano T, Wiegertjes G. Properties of carotenoids in fish fitness: a review. *Mar. Drugs.* 2020;18:1-17.
5. Swain S, Hauzoukim, Acharya AP, Mohanty B. Use of carotenoid supplementation for enhancement of pigmentation in ornamental fishes. *J Entomol Zool Stud.* 2020;8(6):636-640.
6. Hien TTT, Loc TV, Tu TLC, Phu TM, Duc PM, Nhan HT, Liem PT. Dietary Effects of Carotenoid on Growth Performance and Pigmentation in Bighead Catfish (*Clarias macrocephalus* Günther, 1864). *Fishes.* 2022;7(1). Available: <https://doi.org/10.3390/fishes7010037>
7. Monica J, Navitha C, Arumugam P, Sivaraj C. Studies on effect of marine macro algae *Enteromorpha intestinalis* as skin color enhancer and as an alternative for fish meal in feed supplemented to ornamental fishes. *Int. J Fish aquat Stud.* 2021;9(2):201-205.
8. Lakshmi GS, Martin P, Elumalai K, Kasinathan LD. Effect of different concentrations of feed enriched with carrot, beetroot and Spirulina powder on growth performance and survival rate of Albino Tiger barb, *Puntius tetrazona*. Bleeker, 1855 (Cypriniformes: Cyprinidae). *IntJ Adv ResBiol Sci.* 2015;2(10):176-186.
9. Andriani Y, Julia RO, Yuliadi LPS, Iskandar I, Rukayadi Y. Improving the Color Quality of the Swordtail Fish through the Supplementation of Butterfly Pea Leaf Meal. *Sarhad J Agric.* 2021;1(37):48-54.
10. Palaparathi AK, Sudhakaran S, Mohan TC, Pamanna D, Kumar PR, Shanthanna P. Evaluation of colour enhance potential of three natural plant pigment sources (African tulip tree flower, red paprika, pomegranate peel) in goldfish (*Carassius auratus*). *Int. J Fish AquatStud.* 2017;5(6): 47-51.
11. Maiti MK, Bora D, Nandeesh TL, Sahoo S, Adarsh BK, Kumar S. Effect of dietary natural carotenoid sources on colour enhancement of Koi carp, *Cyprinus carpio* L. *Int JFishAquat Stud.* 2017;5(4):340-345.
12. Seidgar M, Mohebbi F, Nekuiefard A, Hafezieh M, Dadgar S, Anbi AA, Shiri A. The effect of Artemia urmiana, Earthworm, Cow heart and concentrate as supplementary diets on skin color and pigmentation of Oscar fish (*Astronotus ocellatus*). *Int J AquatSci.* 2019;10(2):88-93.
13. Abidin NAZ, Kormin F, Abidin NAZ, Anuar NAFM, Bakar MFA. The potential of insects as alternative sources of chitin: An overview on the chemical method of extraction from various sources. *Int J Mol Sci.* 2020;21(4978):1-25.
14. Sathyaruban S, Uluwaduge DI, Yohi S, Kuganathan S. Potential natural carotenoid sources for the colouration of ornamental fish: A review. *Aquac Int.* 2021;29: 1507-1528.
15. Rana S, Bari AA, Shimul SA, Mazed MA, Ahmad SK, Nahid AI. Enhancement of body coloration of sword-tail fish (*Xiphophorus helleri*): Plant-derived bio-resources could be converted into a potential dietary

- carotenoid supplement. Heliyon. 2023;9 (e15208):1-6.  
Available:<https://doi.org/10.1016/j.heliyon.2023.e15208>.
16. Henry M, Gasco L, Piccolo G. Use of insects in the diet of farmed fish: Past and future. Anim Feed Sci Technol. 2015; 203:1-22.
  17. Ulrich SP. Native fish species boosting Brazilian's aquaculture development. Acta Fish Aquat Res. 2017;5:1–9.
  18. Pulcini D, Capoccioni F, Franceschini S, Martinoli M, Tibaldi E. Skin pigmentation in gilthead seabream (*Sparus aurata* L.) fed conventional and novel protein sources in diets deprived of fish meal. Animals. 2020;10(11) 2127- 2138.  
Available:<https://doi.org/10.3390/ani10112138>
  19. Das M, Ganguly A, Haldar P. Effect of food plants on nutritional ecology of two acridids (Orthoptera: Acrididae) to provide alternative protein supplement for poultry. Turkish J Zool.2012;36(5):699-718.
  20. Orinda M, Oloo JA, Magara H, Ayieko M, Roos N. Cricket rearing handbook. Services for science and education stockport, SK4 2BT United Kingdom: Cheshire; 2020;59p.
  21. Bordiean A, Zaniak MK, Stolarski MJ, Peni D. Growth potential of yellow mealworm reared on industrial residues. Agriculture. 2020;10(599):1-12.
  22. Das M, Mandal SK. *Oxya hyla hyla* (Orthoptera: Acrididae) as an Alternative Protein Source for Japanese Quail. Int Sch Res Notices. 2014;(2014): 269810.  
Available:<https://doi.org/10.1155/2014/269810>.
  23. Magara HJO, Niassy S, Ayieko MA, Mukundamago M, Egonyu JP, Tanga CM, Kimathi EK, Ongere JO, Fiaboe KKM, Hugel S, Orinda MA, Roos N, Ekesi S. Edible crickets (Orthoptera) around the world: Distribution, nutritional value, and other benefits—A Review. Frontiers in Nutrition. 2021;  
Available: [www.frontiersin.org](http://www.frontiersin.org).
  24. Liu C, Masri J, Perez V, Maya C, Zhao J. Foods. 2020;9(151):2-10.
  25. AOAC. Official methods of analysis. 18th ed. Revised. Washington, DC, USA: Association of Official Analytical Chemists; 2006.
  26. Cyanotech. Analysis of Beta-carotene and Total carotenoids from spirulina (Spectrophotometric method). Spirulina pacifica. Technical Bulletin, 003b, Cyanotech Corporation; 2002.  
Available:[www.cyanotech.com](http://www.cyanotech.com).
  27. Tiewsoh W, Singh E, Nath R, Surnar SR, Priyadarshini A. Effect of carotenoid in growth and colour enhancement in gold fish, *Carassius auratus* (L.). J. Exp. Zool. India. 2019;22(2):765-771.
  28. APHA. Standard methods for examination of water and waste water American Public Health Assoc. 12th ed. Washington: DC; 1989;1452.
  29. Chapman FA. Ornamental fish culture, freshwater. Encyclopedia of Aquacult.. RR Ed. Stickney: 2000;602-610. John Wiley & Sons, New York.
  30. Pailan GH, Sinha A, Kumar M. Rose petals meal as natural carotenoid source in pigmentation and growth of rosy barb (*Puntius Conchoniis*). Indian J Anim Nutr. 2012;29 (3):291-296.
  31. Chong ASC, Ishak SD, Osman Z, Hashim R. Effect of dietary protein level on the reproductive performance of female swordtails, *Xiphophorus helleri* (Poeciliidae). Aquac. 2004;234:381-392.
  32. Johnston G, Kaiser H, Hecht T, Oellermann L. Effect of ration size and feeding frequency on growth, size distribution and survival of juvenile clown fish. *Amphiprion percula*. J Appl Ichthyol. 2003;19:40-43.
  33. Sapkale PH, Patil SV, Yadav SR, Gitte MJ. Growth performance and feed conversion efficiency of *Xiphophorus maculatus* (Gunther, 1866) Juveniles at different daily feeding rates. Ecol Environ Conserv. 2017;23(4):2125-2128.
  34. Rad F, Koksal G, Kindir, M. Growth performance and food conversion ratio of Siberian Sturgeon (*Acipenser baeri* Brandt) at different daily feeding rates. Turkish J Vet Anim Sci. 2003;27:1085-1090.
  35. Weisburger JH, Chung FL. Mechanisms of chronic disease causation by nutritional factors and tobacco products and their prevention by tea polyphenols. Food Chem Toxicol. 2002;40:1145-1154.
  36. Segner HP, Arend K, Von P, Schmidt. The effect of feeding astaxanthin to *Oreochromis niloticus* and *Colisalabiosa* on the histology of the liver. Aquac.1989;79:381-390.
  37. Amar EC, Kiron V, Satoh S, Watanabe T. Influence of various dietary synthetic carotenoids on bio-defense mechanisms in



- rainbow carotenoids on bio-defense mechanisms in rainbow trout *Oncorhynchus mykiss*. Aquac Res. 2001;32:162-163.
38. Singh RN, Kumar A. Beetroot As a carotenoid Source on growth and colour development in red swordtail *Xiphophorus helleri* Fish. Imp J Interdiscip Res. 2016;2(10):637-642.
39. De-la MGI, Arredondo-Figueroa JL, Ponce-Palafox JT, Barriga-Sosa IA, Vernon-Carter JE. Comparison of red chilli *Capsium annuum* oleoresin and astaxanthin on rainbow trout *Oncorhynchus mykiss* fillet pigmentation. Aquac. 2006;258:487-495.
40. Sinha A, Asimi OA. China rose. *Hibiscus rosasinensis* petals: A potent natural carotenoid source for goldfish *Carassius auratus* L. Aquac Res. 2007; 38:1123-1128.
41. Mirzaee S, Sabani A, Rezaee S, Hosseinzadeh M. The Effect of synthetic and natural pigments on the color of the guppy fish *Poecilia reticulata*. Glob Vet.2012;9(2):171-174.
42. Storebakken T, No HK. Pigmentation of rainbow trout. Aquac. 1992;100(1-3):209-229.
43. Torrissen OJ, Hardy RW, Shearer KD. Pigmentation of salmonids: carotenoid deposition and metabolism. Aquat Sci. 1989;1:209-225.
44. Kiriratnikom S, Zaa R, Suwanpugdee A. Effects of various levels of Spirulina on growth performance and pigmentation in goldfish *Carassius auratus*. Songklanakarin J Sci Technol. 2005;27: 133-139.
45. Xu X, Jin Z, Wang H, Chen X, Wang C, Yu S. Effect of astaxanthin from *Xanthophyllomyces dendrorhous* on pigmentation of goldfish, *Carassius auratus*. J World Aquac Soc. 2006;37:282-288.
46. Yanar M, Erçen Z, Hunt AO, Büyükçapar HM. The use of alfafa, *Mendicago sativa* as natural carotenoid source in diets of goldfish, *Carassius auratus*. Aquac. 2008; 284:196-200.
47. Ha BS, Kang DS, Kim JH, Choi OS, Ryu HY. Metabolism of dietary carotenoids and effects to improve the body color of cultured flounder and red seabream. Bull.Korean Fish. 1993;38:331-338.
48. Amla A, Villar-Martinez D, Juan C, Rogel O, Pablo E, Espinoza V, Adrian G, Gutierrez Q, Lara-Flores M. The effect of marigold (*Tagetes erecta*) as natural carotenoid source for the pigmentation of goldfish (*Carassius auratus* L.). Res J Fish and Hydrobio. 2013;8(2):31-37.
49. Jagadeesh TD, Murthy HS, Surendranath SV, Panikkar P, Manjappa N, Mahesh V. Effect of supplementation of marigold (*Tagetes erecta*) oleoresin on growth, survival and pigmentation of rosy barb, *Puntius conchoni* (Hamilton). The Bioscan. 2015;10(3):1431-1435.
50. Hancz C, Magyary I, et al. Evaluation of colour intensity enhanced by paprika as feed additive in goldfish and Koi carp using computer assisted image analysis. Fish Sci. 2003;69(6):1158-1161.

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