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Essential Nutritional Requirements and Effective Feeding Strategies for Commercially Important Ornamental Fish: A Review

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ABSTRACT

This review examines the essential nutritional requirements and effective feeding strategies for ornamental livebearers, specifically guppies, swordtails, platies, and mollies. Recognizing their omnivorous nature, this report emphasizes the importance of a balanced diet that includes proteins, lipids, carbohydrates, vitamins, minerals, and feed additives crucial for growth, health, and reproductive success. Reviewed studies highlight the varying dietary protein needs across different life stages, with requirements estimated at 30-45% for guppies and swordtail, and 40% for platy with essential amino acids. The role of lipids and carbohydrates in energy provision and overall health is also discussed, noting the significance of essential fatty acids and colour additives which are not synthesized de novo by fish. The review also identifies key minerals and vitamins essential for immunity and health, alongside various feed additives that enhance feed efficiency and health benefits. Insights into practical feeding management strategies are presented, showcasing the impact of feeding frequency on growth and reproductive performance. While live feeds remain popular due to their high nutritional value, this review advocates for adopting formulated feeds to improve sustainability and reduce production costs in aquaculture. Moreover, it highlights the need for further research into utilising alternative protein sources and feed formulations to optimize livebearers' growth and health in aquaculture and ornamental settings. Maintaining a comprehensive understanding of livebearers' unique nutritional requirements is critical for enhancing fish welfare and cultivating thriving ornamental populations in home aquariums and commercial breeding operations.

Keywords: Balanced nutrition, guppies, mollies, platies, swordtails.

1. INTRODUCTION

A greater understanding of the nutritional needs of different fish species, coupled with advancements in feed production technology, has enabled the creation and application of formulated feeds to supplement or replace natural feeds within the aquaculture industry.[1] The nutritional needs and feeding strategies of livebearers, such as guppies, swordtails, platies, and mollies are critical to their health and well-being in both aquaculture and ornamental settings. As popular choices among aquarium enthusiasts, these species demand a diet that is not only balanced but also tailored to their unique physiological requirements. Unlike traditional food fish, ornamental livebearers have specific dietary preferences and needs, which necessitate a careful consideration of their nutritional intake.

Livebearers are generally classified as omnivorous, thriving on a diverse diet that includes plant matter, algae, and insect larvae in their natural habitats.[2] In controlled

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environments, these fish are typically provided with commercial feeds, including flakes, pellets, and freeze-dried options, designed to mimic their natural nutritional profiles. The formulation of such feeds requires a focus on several key nutritional components: proteins, lipids, carbohydrates, vitamins, minerals, and various feed additives that collectively support their growth, health, and reproductive success.[3]

This introduction highlights the vital importance of understanding the unique nutritional requirements of livebearers and the mechanisms by which these needs can be effectively met through appropriate feeding strategies. As research in this area continues to evolve, effective feeding regimes will undoubtedly enhance both the sustainability of aquaculture practices and the health of ornamental fish populations, ensuring that these vibrant creatures thrive in both home aquariums and commercial breeding operations.

The feeding behavior and habits of ornamental fish can differ significantly between livebearers, such as guppies, swordtails, platies, and mollies, and egg layers, like bettas or cichlids. One of the primary distinctions lies in their reproductive strategies and associated feeding processes.

Livebearers possess developed internal reproductive organs, allowing them to give birth to free-swimming fry rather than laying eggs.[4] This characteristic enables them to start feeding on formulated diets from the very first day of life. As a result, fry can quickly adapt to a variety of commercial feeds, including finely crushed flakes or specially formulated fry foods. In contrast, egg-laying species typically have undeveloped digestive systems at hatching, requiring them to rely primarily on their yolk sacs for initial nourishment.[5] This limitation means that these fish are not able to consume external feed immediately after hatching. Once they deplete their yolk sacs, they must be introduced to appropriate starter foods, which are usually small enough to accommodate their size and developmental stage. This delay in feeding can influence their early growth and survival rates.

2. NUTRIENT REQUIREMENTS

The guppy, swordtail, platy, and molly are frequently cultured commercial ornamental fishes in Sri Lanka and considered omnivorous.[6] They are required balanced nutrition containing protein, lipids, carbohydrates, vitamins, minerals, and other feed additives to satisfy the physiological needs of growth and reproduction.[7] They prefer a wide variety of foods in the wild such as algae and aquatic insect larvae; however, aqua farmers could feed them flakes, formulated pellets, and freeze-dried foods. A formulated diet for aquarium feeding should have notable characteristics such as being nutritionally balanced, palatable and resistant to crumbling, water stable buoyant, and inexpensive.[8]

2.1 Protein and amino acids

The significance of an adequate protein supply cannot be overlooked, as it plays a fundamental role in the growth and development of livebearers. Protein requirements fluctuate with age, necessitating a thoughtful approach to feeding strategies that adjust to the life stages of the fish.[9] Fish protein requirements first necessitate providing essential amino acids, followed by supplying non-essential amino acids or adequate amino nitrogen for their synthesis [10]

The previous records demonstrate the nutrient requirements of ornamental fishes. [3,7,9,11-13] The guppy, swordtail, and Platy fish require around 30-40 % dietary protein.[6] an essential nutrient for ornamental fish growth. Protein requirements decrease while fish grow. [14] The primary protein source used in aqua feed production is primarily fishmeal because of its high protein content, essential amino acids, admirable palatability, and growth factors;[15] however, several plant and animal derivatives contain an appreciable quantity of protein with an excellent amino acid profile that can be utilized during feed formulation.[16,17] Already, a large number of by-products such as fish waste and by-catches,[18] soybean grain,[19] ground nut cake,[20] duckweed,[21] and *Azolla sp*[22] are used

as possible alternative protein sources in food and ornamental fish feed formulation; however, the information on utilization of these plant and animal-derived products in guppy and swordtail in practical farming conditions yet remains scarce. Furthermore, recent investigations into replacing fishmeal in ornamental fish feed have focused on various plant- and animal-based alternatives, aiming to address sustainability concerns while maintaining the nutritional profile necessary for optimal fish growth and health such as field cricket meal for guppies and swordtails [23], vermi-incorporated feed for the seed production of two freshwater ornamental fish, *Xiphophorus helleri* and *Poecilia sphenops,* [24] Black Soldier Fly (*Hermetia illucens*) larvae Meal for Koi Carp (*Cyprinus carpio* var. *koi*)[25], and single-cell protein (SCP) derived from methanotrophic bacteria (*Methylococcus capsulatus*, Bath) for barramundi fry (*Lates calcarifer*),[26] These investigations reflect a broader trend towards sustainable aquaculture practices that minimize dependency on traditional fishmeal. The integration of alternative protein sources not only supports the health and growth of ornamental fish but also helps to alleviate the pressure on fish stocks, promoting a more environmentally friendly aquaculture industry.

Table 1: Nutrient requirements of livebearers

Fish	Crude protein %	Crude lipid %	Ash %	Digestible energy	Effect	Refs
Guppy fingerling *Poecilia reticulata*	30	10	4	4 Kcal/g	Growth	[12]
	31	NR	NR	NR	Reproductive performance	[6]
	30-40	NR	NR	13 KJ/g	Body weight, ovary weight, gonado-somatic index and number of yolky oocytes	[27]
	43	9.5	NR	NR	Significant specific growth rate and reproductive rate	[28]
Brooder Guppy *Poecilia reticulata*	35	7	9	NR	Weight gain and specific growth rate	[29]
Swordtail fingerling *Xiphophorus hilleri*	40	6	4	4 Kcal/g	Growth	[12]
	30	12	NR	20.9 KJ/g	Optimum growth and reproductive performance	[30]
	45	6	NR	NR	Specific growth rate	[31]
Swordtail Brood stock *Xiphophorus hilleri*	30	NR	NR	16.5 KJ/g	Reproductive performance	[32]
Platy fish fry *Xiphophorus maculatus*	40	6	NR	NR	Growth rate	[33]
	40	10	11	NR	Optimum survival and growth rate	[34]
Black molly, *Poecilia sphenops*	29	NR	NR	NR	Weight gain, specific growth rate, absolute fecundity, and mean gonadosomatic index	[35]
	47	NR	NR	NR	Specific growth rate and mean weight gain	[36]
Black molly, *Poecilia latippina*	40	6	NR	NR	Nutrient utilization in terms of weight gain, specific growth rate, food conversion ratio and protein efficiency ratio	[12]

NR – Not recorded

The protein requirements have been studied in various ornamental fishes at their different life stages.[15] According to the summarized records of the previous studies, the dietary protein requirements of livebearers seem to be higher than those of other nutrient components; however, significant differences seem to exist among species: guppy (30 - 43%), swordtail (30 – 45%), platy (40%), and molly (29 - 47%). An increase in the growth and reproductive performance achieved by taking the dietary protein has been proven in previous studies (Table 1).

Understanding the specific amino acid needs of fish is crucial for formulating protein mixtures that effectively supplement deficient amino acids, thereby optimising growth and protein efficiency. Research shows that fish on diets lacking any of the 10 essential amino acids (leucine, isoleucine, lysine, histidine, tryptophan, valine, phenylalanine, threonine, methionine, and arginine) did not grow until these amino acids were included. Conversely, fish on diets deficient in non-essential amino acids (alanine, aspartic acid, citrulline, cysteine, glutamic acid, glycine, proline, hydroxyproline, serine, and tyrosine) grew similarly to those on a complete diet.[37] The demand for essential amino acids in ornamental fish larvae is likely greater than that of juvenile food fish.[9] This may relate to a crucial growth stage for larvae occurring in a brief period (20 days) or the absence of a selective system for macromolecular protein absorption in larvae compared to juvenile fish.[38] Additionally, certain insects (such as field cricket meal) can provide essential amino acids for formulating guppy diets.[23]

2.2 Lipids

Apart from protein, essential fatty acids and carbohydrates also contribute to energy provision and overall health, necessitating a holistic view of their dietary needs.[9] Dietary lipid is a vital nutrient source of energy for animals. Fishes can synthesise de nova fatty acids from acetate as a precursor[39] except for the three essential fatty acids "linolenic acid" (18:3n-3); "linoleic acid" (18:2n-6) and "arachidonic acid" (20:4n-6); however, they could be provided in the dietary feed.[15] Two main sources of lipids are utilized in aquaculture such as marine oil and some vegetable oils; however, due to the high cost and easy oxidation of vegetable oils, the marine oils are preferred for the feed formulation.[3] Researchers found alternative ingredients such as beef heart, *Artemia,* and *Streptocephalus simplex* enriched with essential fatty acids for making ornamental fish feed.[40] Recent experiments in aquaculture have focused on identifying sustainable and cost-effective alternative lipid sources to enhance the nutritional profiles of fish feeds while minimizing environmental impacts.[41] One promising alternative is the inclusion of plant-based oils, such as those derived from microalgae, which are rich in omega-3 fatty acids.[42] Insects, particularly larvae from black soldier flies and other species, have also emerged as a significant alternative lipid source.[43]

2.3 Carbohydrates

Carbohydrate is also an important raw material, broadly categorized as either non-starch polysaccharides or starches.[44] Increased starch gelatinization characteristically increases water solubility, as well as pellet durability.[45] Carbohydrates are not necessary for a fish diet; they are added to promote bulk, lower feed costs, and enhance the binding of ingredients. An adequate carbohydrate intake seems to eliminate the necessity for gluconeogenesis. In addition to reducing diet costs, carbohydrates also enhance the binding capacity of fish feed pellets.[37] Complex carbohydrates can be digested by some herbivorous ornamental fish using microflora present in their gut; however, the ability of the digestion varies from species to species: 70% in goldfish and 50% gourami.[46] Cooked carbohydrates such as corn flour, wheat, and other cereals are used in the feed formulation.[2] There is no alternative carbohydrate requirement for live bearers. However, cassava flour serves as a carbohydrate source for ornamental fish.[47 Additionally,

cassava flour has been shown to enhance growth, digestive efficiency, and liver glycometabolism in common carp.[48]

2.4 Minerals and Vitamins

Sufficient minerals and vitamins are essential to ornamental fish for good health and enhanced immunity.[15] Ornamental fish are capable to absorb some water-soluble minerals (Calcium and Phosphorous) from the water.[49] Among all the minerals essential for fish, phosphorus stands out as crucial for growth, bone mineralisation, and the metabolism of lipids and carbohydrates. Its inclusion in the diet is necessary due to its low presence in natural water.[9]

Vitamins are organic substances needed in relatively small amounts for the functioning of most life forms, yet certain organisms cannot synthesise them.[15] Water-soluble vitamins are particularly susceptible to nutrient loss through leaching. A significant proportion of vitamin C, vitamin B12, choline, and pantothenic acid is depleted in water just 30 seconds after feeding some commercial flake diets.[50]

Different additives may contain varying levels of essential vitamins, minerals, and pigments that can directly influence the fish's colouration and health.[51] Usually, vitamin and mineral premix is added in adequate amount to the diet; however, adding some dietary ingredients (Bone ash, chalk rock, lime stone and oyster shell) into the feed is also recorded in the previous studies. Guppy requires 0.01% Zinc, 0.53–1.23% phosphorous, 0.008%, Iron, and 0.054% Magnesium[49,52,53] for their weight gain, mineralisation, Prevention of hypochromic, and microcytic anaemia.

2.5 Feed additives

Other feed additives studied are colour pigments, binders and binding agents,[54] enzyme supplements,[55] microbial supplements and health-promoting compounds[56] and growth promoters. The usage of these additives depends on the manufacturing process, country of production, and target species.[57]

As shown in Table 1, several investigations were done to assess the nutrient requirement and its effect on fish development. They identified the optimum nutrient amount for fish that show better growth and nutrient utilization.

3. FEEDING MANAGEMENT

Fish feed management includes correct feed selection, feeding type, method, and frequency[58]. Efficient feed management can reduce the overall culture cost, and it is vital for sustainable and economical fish production.[59]

A practical, cost-cutting strategy exists in optimizing species-specific feeding in an aquaculture operation. Many research studies have been carried out on the effect of feeding frequency on growth and reproductive performance in edible fish. However, little attention has been paid to the growth and reproduction of ornamental fish like angel Fish,[60] goldfish,[61] zebrafish,[62] Amazonian ornamental fish *Pyrrhulina brevis,*[63] Amazon ornamental fish *Nannostomus beckfordi,*[64] and *Heros severus.*[65]

The optimum feeding frequency of live bearers is species, size, and age specific for maximizing the growth.[66] The highest specific growth rate obtained by feed meal three time a day in red swordtail *Xiphophorus helleri* Juvenile[67] and Guppy (*Poecilia reticulata*) Juveniles.[68] Moreover, three times meal fed per day influenced on reproductive performance (gonad weight and gonadosomatic index increased and highest number of fry).[67]

3.1 Aquaculture feeds

Three different feeds are used in aquaculture practices: live food, supplementary feeds, and complete feeds.[8] Because of having high nutritional value, the majority of ornamental fish entrepreneurs still depend on live feed, such as *Azolla pinnata*,[69] *Artemia*, bloodworm and earthworm for Swordtail;[70] Daphnia, blood worms, and mosquito larvae feed for swordtail brood stock;[71] microalgae for guppy fry;[72] field and house cricket meal for guppy,[23] cricket meals for swordtail,[73] super worm,[74]

and egg yolk,[75] and *Spirulina* for guppy[76] and *Spirulina* and *Chlorella* for guppy.[77] For example, juvenile Swordtail gained more protein content in their body and showed a significant daily growth trend by fed with live food (*Tubifex*) than those of other feeds (formulated custard and commercial feed).[78] Similarly, the live feed, *Artemia* nauplii, enhances the growth of fry guppy in terms of larval length, weight and specific growth rate (SCR) than the formulated diet tested.[79] Furthermore, James and Sampath (2003)[67] experimented with the feed intake, conversion ratio, ovary weight, and fertility in red Swordtail, *Xiphophorus helleri* fed with live and commercial food. The results reveal that the tested parameters significantly affected the fish fed with *Artemia* more than those that consumed the pelleted diet.

However, aquaculture practices could improve the sustainability of the production of live foods; moreover, culturing live foods requires considerable space and expense.[80] On the other hand, formulated feeds can be kept for a significant time and are easy to maintain. Also, the production cost is lower than that of live food culturing.[81]

However, a comparative analysis was carried out by Debnath *et al*. (2022)[78] to test the growth rate of juvenile Swordtail among the groups fed with live feed (*Tubifex*), formulated egg custard, and two commercial feeds (aquarium feed and fish feed) respectively. The survival rate was the same in all the treatments. Still, the protein content in the body and trend of the daily growth was significantly increased in the fish fed with *Tubifex* and custard than those of other groups during the experimental period.

The structure and size of the diet influence the growth and survival rate of ornamental fish. Harpaz *et al.* (2005)[82] tested the different prepared diets (powdered extruded feed and drum-dried flakes) on ornamental guppy fish fry. They concluded that the powdered diet could be consumed rapidly by the fish without leeching vital nutrients from the feed before being engulfed by the fish, probably leading to better growth.

3.2 Cost Effectiveness

Fish feed is a significant expenditure for fish farmers. Good fish feed management can reduce overall culture costs, improve the fish farm environment and ensure the healthy growth of the fish stock. The cost-effectiveness and suitability of many manufactured feeds on the market must be recorded. Kumaratunga and Radampola (2019)[83] was carried out to investigate the suitability of three commercial feeds and their effects on the growth and reproductive performance of guppy *Poecilia reticulate.*[83] There are many reports on using various low-cost raw ingredients in the diet of the guppy [84] and swordtail species.[67]

4. FUTURE OUTLOOKS

This review underscores the critical importance of understanding the nutritional requirements and feeding strategies of ornamental livebearers, including guppies, swordtails, platies, and mollies. While significant advancements have been made in feed formulation and aquaculture practices, gaps remain in our comprehensive understanding of the optimal nutrition for these species at different life stages. Variability in protein needs highlights the necessity for more species-specific studies to refine feeding protocols, especially given the differences observed in dietary protein recommendations (30-45% for swordtails compared to 29-47% for mollies).

Furthermore, although alternative protein sources, such as plant and animal by-products (insect meals, and single-cell protein), offer promising prospects for improving sustainability in feed formulations, limited research exists on their practical applications within aquaculture systems dedicated to these livebearers. Future studies should focus on evaluating the efficacy of these alternatives under real-world conditions, emphasizing their impact on growth rates and reproductive performance.

Moreover, while live feeds continue to dominate due to their high nutritional value, the benefits of formulated feeds must be more thoroughly investigated. Ensuring that these

feeds are nutritionally balanced, cost-effective, and suitable for long-term use in aquaculture is crucial for enhancing the health of ornamental fish populations. Research should expand into examining the long-term effects of feeding frequency and regimen adjustments, which have already demonstrated positive impacts on growth and reproduction among several fish species.

Ultimately, bridging these knowledge gaps will improve the welfare of ornamental livebearers in home aquariums and commercial breeding settings and contribute to the sustainability of aquaculture practices. Continued investment in research efforts focusing on the nutritional optimization of these captivating fish is essential for fostering vibrant, healthy populations across diverse environments.

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REFERENCES

1. Brum, A., Magnotti, C., Tsuzuki, M.Y., Sousa, E.M.D.O., Mouriño, J.L.P., Martins, M.L., Lopes, R.G., Derner, R.B., & Owatari, M.S., Pivotal Roles of Fish Nutrition and Feeding: *Recent Advances and Future Outlook for Brazilian Fish Farming Fishes*, 2025. **10**(2): 47.
2. Ahilan, B., Felix, N., & Santhanam, R., *Textbook of Aquariculture. Daya Publishing House*, a division of Astral International Pvt. Limited, 2008.
3. Velasco-Santamaría, Y., & Corredor-Santamaría, W., Nutritional requirements of freshwater ornamental fish: *a review. Revista MVZ Córdoba*, 2011. 16(2), 2458-2469.
4. Alderton, D., Livebearers: *Understanding guppies, mollies, swordtails and other*s. Companion House Books, 2003.
5. Swain, H.S., Bhattacharya, S., Meena, D.K., Sahoo, A.K., & Das, B.K., Breeding culture of Ornamental Fishes. *Training Manual*, 2019: 7.
6. Dahlgren, B.T., The effects of three different dietary protein levels on the fecundity in the guppy, Poecilia reticulata (Peters). *Journal of Fish Biology*, 1980. 16(1): 83-97.
7. Joachim, W.H., & Felistas, P.P., *Handbook on ingredients for aquaculture feeds*. Kluwer Academic Publishers, London, 2000. 478.
8. Craig, S.R., Helfrich, L.A., Kuhn, D., & Schwarz, M.H., Understanding fish nutrition, feeds, and feeding. *Virginia Cooperative extension*, 2017.
9. Sales, J., & Janssens, G.P., Nutrient requirements of ornamental fish. *Aquatic Living Resources*, 2003. 16(6): 533-540.
10. Macartney, A., *Ornamental fish nutrition and feeding. In: Kelly, N.C., Wills, J.M. (Eds.), Manual of Companion Animal Nutrition and Feeding*. British Small Animal Veterinary Association, Gloucestershire, UK, 1996: 244–251.
11. Lovell, R.T., Nutrition of ornamental fish. Kirk's current veterinary therapy XIII: *small animal practice*, 2000. 1191-1196.
12. Mohanta, K.N., & Subramanian, S., Nutrition of common freshwater ornamental fishes. *Indian Council of Agricultural Research*, 2011. Old Goa - 403 402, Goa, India.
13. Royes, J.A.B., & Chapman, F.A., *Preparing Your Own Fish Feeds*: 2003. Cir 97/FA097, 2/2003. EDIS, 2003(6).
14. Ruby, P., Athithan, S., Ahilan, B., & Sugumar, G., Evaluation of Aquavi Met-Met supplements on the growth performance of Pacific white shrimp, Litopenaeus vannamei (Boone, 1931). *Journal of Experimental Zoology India*, 2017. 20(2).
15. Jobling, M., National Research Council (NRC): *Nutrient requirements of fish and shrimp:* The National Academies Press, Washington, DC, 2011, 376+ XVI pp,£ 128 (Hardback), ISBN: 978-0-309-16338-5.
16. Agboola, J.O., Yossa, R., & Verreth, J., Assessment of existing and potential feed resources for improving aquaculture production in selected Asian and African countries. *Monographs*.2019.

17. Hardy, R.W., Utilization of plant proteins in fish diets: effects of global demand and supplies of fishmeal. *Aquaculture research*, 2010. 41(5):770-776.
18. Afreen, M., & Ucak, I., Fish processing wastes used as feed ingredient for animal feed and aquaculture feed. *Journal of Survey in Fisheries Sciences*, 2023. 55-64.
19. Refstie, S., Storebakken, T., Baeverfjord, G., & Roem, A.J., Long-term protein and lipid growth of Atlantic salmon (Salmo salar) fed diets with partial replacement of fish meal by soy protein products at medium or high lipid level. *Aquaculture*, 2001. 193(1-2): 91-106.
20. Ghosh, K., & Mandal, S., Nutritional evaluation of groundnut oil cake in formulated diets for rohu, Labeo rohita (Hamilton) fingerlings after solid state fermentation with a tannase producing yeast, Pichia kudriavzevii (GU939629) isolated from fish gut. *Aquaculture Reports*, 2015. 2: 82-90.
21. Anthonius, C., Seok Kian Yong, A., & Fui, C.F., Supplementation of duckweed diet and citric acid on growth performance, feed utilization, digestibility and phosphorus utilization of TGGG hybrid grouper (Epinephelus fuscoguttatus x Epinephelus lanceolatus) juvenile. Songklanakarin *Journal of Science & Technology*, 2018. 40(5): 1009-1016.
22. Das, M., Rahim, F.I., & Hossain, M.A., Evaluation of fresh Azolla pinnata as a low-cost supplemental feed for Thai Silver Barb Barbonymus gonionotus. *Fishes*, 2018. 3(1): 15.
23. Perera, G.C. & Bhujel, R.C., Replacement of fishmeal by house cricket (Acheta domesticus) and field cricket (Gryllus bimaculatus) meals: Effect for growth, pigmentation, and breeding performances of guppy (Poecilia reticulata). *Aquaculture Reports*, 2022. 25: 101260.
24. Sharma, K., & Garg, V. K., Utilization of vermi-incorporated feed for the seed production of two freshwater ornamental fish, Xiphophorus helleri and Poecilia sphenops. *Biomass Conversion and Biorefinery*, 2024. 14(18): 23163-23172.
25. Linh, N. V., Wannavijit, S., Tayyamath, K., Dinh-Hung, N., Nititanarapee, T., Sumon, M. A. A., Srinual, O., Permpoonpattana, P., Van Doan, H., & Brown, C. L., Black soldier fly (Hermetia illucens) larvae meal: A sustainable alternative to fish meal proven to promote growth and immunity in koi carp (Cyprinus carpio var. Koi). *Fishes*, 2024. 9(2): 53.
26. Samsing, F., Sullivan, R., Truong, H., Rombenso, A., Sangster, C. R., Bannister, J., Longshaw, M., & Becker, J. A., Replacement of fishmeal with a microbial single-cell protein induced enteropathy and poor growth outcomes in barramundi (Lates calcarifer) fry. *Journal of Fish Diseases*, 2024. 47(9), e13985.
27. Shim, K.F., & Chua, Y.L., Some studies on the protein requirement of the guppy, Poecilia reticulata (Peters). *Journal of Aquariculture and Aquatic Science,* 1986. 4: 79-84.
28. Kithsiri, H.P., Sharma, P., Zaidi, S.S., Pal, A.K., & Venkateshwarlu, G., Growth and reproductive performance of female guppy, Poecilia reticulata (Peters) fed diets with different nutrient levels. *Indian Journal of Fisheries*, 2010. 57(1): 65-71.
29. Suting, P.S., Mandal, S.C., & Patel, A.B., Effect of different dietary lipid sources on growth and reproductive performance of guppy (Poecilia reticulata). *Israel Journal of Aquactic ISR*, 2013. 65: 1-6.
30. Ling, S., Hashim, R., Kolkovski, S., & Chong Shu-Chien, A., Effect of varying dietary lipid and protein levels on growth and reproductive performance of female swordtails Xiphophorus helleri (Poeciliidae). *Aquaculture Research*, 2006. 37(13): 1267-1275.
31. Kruger, D.P., Britz, P.J., & Sales, J., Influence of varying dietary protein content at three lipid concentrations on growth characteristics of juvenile swordtails (Xiphophorus helleri, Heckel 1848). *Aquarium Sciences and Conservation*, 2001. 3: 275-280.

32. Chong, A.S., Ishak, S.D., Osman, Z. and Hashim, R., Effect of dietary protein level on the reproductive performance of female swordtails Xiphophorus helleri (Poeciliidae). *Aquaculture* , 2004. 234 (1-4): 381-392.
33. Priyadarshana, M.K.C., Walpita, C.N., Ruwandeepika, H.A.D., Magamage, M.P.S., & Withanage, P.M., Influence of the dietary protein and fat contents on the growth performances of Xiphophorus maculatus: A preliminary study. *AgInsight*, 2022: 273-275
34. Sapkale, P.H., Patil, S.V., Yadav, S.R., & Gitte, M.J., Growth performance and feed conversion efficiency of Xiphophorus maculatus (Gunther, 1866) Juveniles at different daily feeding rates. *Ecology, Environment and Conservation*, 2017. 23(4):2125-2128.
35. Pandey, A., Kaur, V.I., Srivastava, A., Datta, S.N. and Singh, A., Effect of formulated feeds with different nutrient levels on growth and reproductive performance of molly, Poecilia sphenops (Valenciennes). *Animal Nutrition and Feed Technology*, 2016. 16(1): 61-70.
36. Verma, H.O., Mandal, S.C., & Pal, J., Effect of different feeds on the growth, survival and reproductive performance of live bearer black molly (Poecilia sphenops). *Journal of Experimental Zoology*, 2015. 18(2): 615-619.
37. Pandey, B., & Sahu, N. P., Nutrient Composition of Artificial Feeds for Aquarium Fishes. *Journal of Basic and Applied Biology*, 2011. 5(1), 158-162.
38. Fiogbé, E.D., & Kestemont, P., An assessment of the protein and amino acid requirement in goldfish (Carassius auratus) larvae. *Journal of Applied Ichthyology,* 1995. 11: 282–289.
39. Castell. J.D., Review of lipid requirements of finfish. In: Finfish nutrition and fish feed technology. *Schriften BFF*. Hamburg /Germany . 1979. 115(2), 59-84.
40. Ako, H., Tamaru, C.S., Asano, L., & Yamamoto., Achieving natural coloration in fish finder culture. In: Spawning and maturation of aquaculture species. *Proceeding of the 28th UNJR aquaculture panel symposium,* Kihei, Hawaii. 10-12, U NJR Technical Report, 2000. 28: 1–4.
41. Coswatte, A. C. W. W. M. C. L. K., Thushari, G. G. N., & Senevirathna, J. D. M. (2024). Prospects of Alternative Lipids as a Sustainable Feed Element for Aquaculture in Asia. In Sustainable Feed Ingredients and Additives for Aquaculture Farming: Perspectives from Africa and Asia. Singapore: *Springer Nature Singapore* 2024: 311-337.
42. Kumari, A., Pabbi, S., & Tyagi, A., Recent advances in enhancing the production of long chain omega-3 fatty acids in microalgae. *Critical Reviews in Food Science and Nutrition*, 2024. 64(29): 10564-10582.
43. Namira, R. W. N. A., Afifah, F. N., & Pratama, A. P. A., Bioconversion of black soldier fly (Hermetia illucens) on agricultural waste: Potential source of protein and lipid, the application (A mini-review). *Advances in Food Science, Sustainable Agriculture, and Agro industrial Engineering*, 2024 7(1): 78-91.
44. Kanmani, N., Romano, N., Ebrahimi, M., Amin, S.N., Kamarudin, M.S., Karami, A., & Kumar, V., Improvement of feed pellet characteristics by dietary pre-gelatinized starch and their subsequent effects on growth and physiology in tilapia. *Food Chemistry*, 2018. 239:1037-1046.
45. De Cruz, C.R., Kamarudin, M.S., Saad, C.R., & Ramezani-Fard, E., Effects of extruder die temperature on the physical properties of extruded fish pellets containing taro and broken rice starch. *Animal Feed Science and Technology*, 2015. 199: 137-145.
46. Pannevis, M.C., *Nutrition of ornamental fish. In: Burger, I.H. (Ed.), The Waltham Book of Companion Animal Nutrition*. Pergamon Press, Oxford, 1993: 85–96.
47. Sutharshiny, S., Deepthi, I.U., & Sivashanthini, K., Improving the floatation of fish feed pellets using starch gelatinization incorporated with palmyrah fruit pulp. *GEORGIA CHAPTER AFS* 2021 Virtual Annual Meeting.
48. Fan, Z., Wu, D., Li, C., Li, J., Wang, L., Zheng, X., Zhang, H., Zhou, M., & Zhou, M., Alternate feeding between high-and low-

carbohydrate based diets improves the growth digestive capacity, liver glycometabolism for common carp (Cyprinus carpio). *Aquaculture Reports*, 2024. 34: 101920.

49. Shim, K.F., & Ho, C.S., Calcium and phosphorus requirements of guppy Poecilia reticulata. *Nippon Suisan Gakkaishi*, 1989. 55(11): 1947-1953
50. Pannevis, M.C., & Earle, K.E., Nutrition of ornamental fish: water soluble vitamin leaching and growth of Paracheirodon innesi. *Journal of Nutrition*, 124: 2633S–2635S
51. Silva, M.M., Reboredo, F.H., & Lidon, F.C., Food colour additives: A synoptical overview on their chemical properties, applications in food products, and health side effects. *Foods*, 2022. 11(3): 379.
52. Shim, K.F., & Lee, T.L., Zinc requirements of the guppy (Poecilia reticulata Peters). *Journal of Aquactic Tropics*, 1993. 8: 81–90.
53. Shim, K.F., & Ng, S.H., Magnesium requirements of the guppy (Poecilia reticulata Peters). *Aquaculture*, 1988. 73:131–141.
54. Abad, E., Llerena, J.J., Sauló, J., Caixach, J., & Rivera, J., Comprehensive study on dioxin contents in binder and anti-caking agent feed additives. *Chemosphere*, 2002. 46(9-10), 1417-1421.
55. Barrows, F.T., & Hardy, R.W., Feed additives. *Enclyclopedia of Aquaculture*, John Wiley and Sons Inc., New York, USA, 2000: 335-340.
56. Abdel-Tawwab, M., & Ahmad, M.H., Live Spirulina (Arthrospira platensis) as a growth and immunity promoter for Nile tilapia, Oreochromis niloticus (L.), challenged with pathogenic Aeromonas hydrophila. *Aquaculture Research*, 2009. 40(9), 1037-1046.
57. Tacon, A.G., Metian, M., & Hasan, M.R., Feed ingredients and fertilizers for farmed aquatic animals: sources and composition (No. 540). *Food and Agriculture Organization of the United Nations (FAO)*. 2009.
58. Houlihan, D., Boujard, T., & Jobling, M., Food intake in fish. *John Wiley & Sons*. 2008.
59. De Silva, S.S., Reducing feed costs in aquaculture: Is the use of mixed feeding schedules the answer for semi-intensive practices?. *Aquaculture Asia*, 2006. 11(4): 7.
60. Kasiri, M., Farahi, A., & Sudagar, M., Effects of feeding frequency on growth performance and survival rate of angel fish, Pterophyllum scalare (Perciformes: Cichlidae). *In Veterinary Research Forum*, 2011. 2(2): 97-102.
61. Hafeez-ur-Rehman, M., Iqbal, K.J., Abbas, F., Mushtaq, M.M.H., Rasool, F., & Parveen, S., Influence of feeding frequency on growth performance and body indices of goldfish (Carrassius auratus). *Journal of Aquaculture Research & Development*, 2015. 6(5), 1.
62. Lawrence, C., Best, J., James, A., & Maloney, K., The effects of feeding frequency on growth and reproduction in zebrafish (Danio rerio). *Aquaculture*, 2012. 368: 103-108.
63. Veras, G.C., Brabo, M.F., Dias, J.A., Abe, H.A., Nunes, Z.M.P., & Murgas, L.D.S., The effect of photoperiod and feeding frequency on larval of the Amazonian ornamental fish Pyrrhulina brevis (Steindachner, 1876). *Aquaculture Research*, 2016. 47(3): 797-803.
64. Abe, H.A., Dias, J.A.R., Sousa, N.D.C., Couto, M.V.S.D., Reis, R.G.A., Paixão, P.E.G., & Fujimoto, R.Y., Growth of Amazon ornamental fish Nannostomus beckfordi larvae (Steindachner, 1876) submitted to different stocking densities and feeding management in captivity conditions. *Aquaculture Research*, 2019. 50(8): 2276-2280.
65. Paixão, D.J.D.M.R., Brabo, M.F., Soares, L.M.O., Campelo, D.A.V., & Veras, G.C., Optimal feeding frequency for Heros severus (Heckel, 1840), an Amazon ornamental fish. *Revista Brasileira de Zootecnia*, 2019. 48.
66. Schnaittacher, G., King, W., & Berlinsky, D.L., The effects of feeding frequency on growth of juvenile Atlantic halibut, Hippoglossus hippoglossus L. *Aquaculture Research*, 2005. 36(4): 370-377.

67. James, R., & Sampath, K., Effects of meal frequency on growth and reproduction in the ornamental red swordtail, Xiphophorus helleri. *The Israeli Journal of Aquaculture – Bamidgeh*. 2003, 55(3): 197-207
68. Norazmi-Lokman, N.H., Baderi, A.A., Zabidi, Z.M., & Diana, A.W., Effects of different feeding frequency on Siamese fighting fish (Betta splenden) and Guppy (Poecilia reticulata) Juveniles: Data on growth performance and survival rate. *Data in brief,* 2020. 32: 106046.
69. Vasudhevan, I., Devi, P.R., & Asokan, K., Effect of Azolla pinnata on Coloration and Leucocytes Count in Platy fish, Xiphophorus maculatus. *International Journal of Research in Fisheries and Aquaculture*. 2015.
70. Anjur, N., & Sandakan, P. (2017). Effect of different natural diets on the growth and survival of Swordtail (Xiphophorus helleri) fry. *Proceedings Festival Agro Makanan dan Bioteknologi*, 11(12): 128-135.
71. Susilawati, R.S., Putra, Y.P., Hutagalung, R.A., & Taufik, M., The Effectiveness Of Providing Different Natural Feed Types Of Swordtail (Xiphophorus Helleri) Broodstock On Crude Birth Rate (Cbr). *Journal of Aquaculture Development and Environment,* 2021. 4(1), 210-217.
72. Nath, P.R., Khozin-Goldberg, I., Cohen, Z., Boussiba, S. & Zilberg, D., Dietary supplementation with the microalgae Parietochloris incisa increases survival and stress resistance in guppy (Poecilia reticulata) fry. *Aquaculture Nutrition*, 2012. 18(2): 167-180
73. Perera, G. C., Senanayake, S. N., Sandaruwani, D. R., Salgadu, M. K. S., Rajapakshe, A. D. W. R., & Athauda, S., Replacement of Fishmeal by Three Cricket Meals (Acheta domesticus, Gryllus bimaculatus, Teleogryllus mitratus) in Swordtail (Xiphophorus helleri) Fry Feed: Effect of Growth, Stress Tolerance, Pigmentation and Histopathological Alterations. *Turkish Journal of Fisheries and Aquatic Sciences*, 2025. 25(7).
74. Kowalska, J., Rawski, M., Homska, N., Mikołajczak,Z., Kierończyk, B., Świątkiewicz, S., Wachowiak, R., Hetmańczyk, K., & Mazurkiewicz, J., The first insight into full-fat superworm (Zophobas morio) meal in guppy (Poecilia reticulata) diets: A study on multiple-choice feeding preferences and growth performance. *Annals of Animal Science*, 2022. 22(1): 371-384.
75. Perera, G.C., Bhujel, R.C., Salin, K., Nguyen, L.T., Sermwatanakul, A., & Lin, O.E., Effect of the varying inclusion levels of the egg yolk powder on growth, stress tolerance, and pigmentation of Guppy (Poecilia reticulata). *Journal of Applied Aquaculture*, 2023. 35(3): 788-803.
76. Dernekbasi, S., Unal, H., Karayucel, I., & Aral, O., Effect of dietary supplementation of different rates of Spirulina (Spirulina platensis) on growth and feed conversion in Guppy (Poecilia reticulata Peters, 1860). *Journal of Animal and Veterinary Advances*, 2010. 9(9): 1395-1399.
77. Perera, G. S. C., Bhujel, R. C., Krishna, S., & Sermwatanakul, A., Comparative Effects of Chlorella and Spirulina on Growth, Pigmentation, Breeding, and Stress Tolerance in Guppy (Poecilia reticulata Peters, 1859). *Journal of Fisheries and Environment,* 2024. 48(3): 80-91.
78. Debnath, S., Sarker, D.S., Kundu, P., Parvez, M.S., Arafat, S.T., Mathew, R.T., Alkhamis, Y.A., Rahman, M.M., & Rahman, S.M., Growth, survival and body protein content of swordtail (Xiphophorus helleri) fed live and formulated feeds. *Advances in Animal Veterinary Science,* 2022.10(2): 335-341.
79. Parameshwaran, K., Edirisinghe, U., Dematawewa, C.M.B., & Nandasena, K.G., Effect of live and formulated feeds on larval growth and survival of guppy (Poecilia reticulata) reared in indoor tanks. *Agricultural Science*, 2018. 9: 171-179.
80. Simhachalam, G., Kumar, N.S., & Rao, K.G., Biochemical composition and nutritional value of Streptocephalus simplex as live feed in ornamental fish culture. *The Journal of Basic & Applied Zoology*, 2015. 72: 66-72.

81. Jones, D.A., Kamarudin, M.S., & Vay, L.L., The potential for replacement of live feeds in larval culture. *Journal of the world Aquaculture Society*, 1993. 24(2): 199-210.
82. Harpaz, S., Slosman, T., & Segev, R., Effect of feeding guppy fish fry (Poecilia reticulata) diets in the form of powder versus flakes. *Aquaculture Research*, 2005. 36(10): 996-1000.
83. Kumaratunga, P.H.S., & Radampola, K., Effect of different commercial feeds on growth and reproductive performance of Guppy, Poecilia reticulata Peters. *Journal of the University of Ruhuna*, 2019. 7(1): 6-11
84. Nishshanka, K.M., Radampola, K., & Bulugahapitiya, V., Effects of partial replacement of dietary fishmeal using plant-protein sources on the growth performance, coloration and liver histology of guppy fry (Poecilia reticulata) in outdoor farming conditions. *Journal of Applied Aquaculture*, 2022. 34(3):715-733.