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Effect of dietary fishmeal protein replacement with decapsulated *Artemia* cysts meal on growth, survival, whole-body composition and pigmentation of Rosy barb, *Puntius conchonius*

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Key words: Carotenoid content, Decapsulated *Artemia* cysts meal, Fishmeal, Growth performance, Rosy barbs

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Abstract

The study evaluated decapsulated *Artemia* cysts meal (DACM) as a source of protein and carotenoid in diets for rosy barb, *Puntius conchonius*. A six-month feeding experiment was conducted in 15 glass aquaria of five feed treatment to evaluate the effects of dietary replacement of fishmeal (FM) protein with DACM on growth performance, food utilization, survival, total carotenoid content in skin and muscle tissue of rosy barb (initial weight of 0.21 to 0.24 gm). Five iso-proteic (30% crude protein) test diets were formulated with DACM to replace FM protein at 0% (D0), 25% (D25), 50% (50), 75% (D75) and 100% (D100) with the inclusion of DACM at the amount of 0%, 10.59%, 21.18%, 31.77% and 42.35% of diet respectively. Rosy barbs fed the D50 diet exhibited significantly highest ($P<0.05$; DMRT) weight gain and specific growth rate (SGR), followed by D75, D25 set and lower in D100 set. Maximum food utilization with the best value of food conversion ratio (FCR) was noted in D50 set. The higher survival of rosy barbs was found in D25, D50 and D75 sets where values did vary significantly (DMRT) and the lower values were obtained from D0 and D100 sets. No significant effect of dietary treatments was found in whole-body composition of experimental fishes. Total carotenoid content in fish skin and muscle tissue was significantly higher in D50 set, followed by D75, D25 set. Thus, the FM protein substituted at 50% with DACM with an inclusion level of 21.18% of diet will be suitable for the rosy barbs, *P. conchonius*.

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Introduction

Ornamental fishes are considered as 'living jewels' due to their attractive coloration and pattern, enchanting size and shape, and fascinating behaviour (Bandyopadhyay *et al.*, 2005). Ornamental fish keeping is the second most popular hobby throughout the world not only due to their aesthetic value but also provide a positive impact on human's psychology, emotions, behaviour and on the cognitive development (Jain *et al.*, 2019; Herzog, 2011). This growing intertest in common people has resulted in increased aquarium fish trade globally. Among the commercially important ornamental fishes, the rosy barb (*Puntius conchonius*) holds acceptance throughout India in ornamental fish sector for its beauty and vibrant reddish colour. It is an indigenous freshwater fish belonging to the family Cyprinidae (Cek *et al.*, 2001).

Success of ornamental fish farming is very much dependent on their brilliant intense dazzling colour which determines their commercial value. Thereby, ornamental fish farmers are persistently trying to enhance skin coloration by adopting various strategies. The vibrant red, orange, yellow colours and their shades of ornamental fishes is due to carotenoid deposition in their skin and muscle tissue (Chatzifotis *et al.*, 2005). Hence, carotenoid is an indispensable nutrient not only for skin colouration but also for healthy growth, metabolism, and reproduction, and for extreme tolerance in variable environmental conditions (Villar-Martinez *et al.*, 2013; Maiti *et al.*, 2017). Since, fishes are not able to synthesize carotenoids denovo (Higuera-Clapara *et al.*, 2006), acquire them from dietary sources. For the colour enhancement of the aqua-cultured species, dietary supplementation of synthetic carotenoid like astaxanthin (red) and canthaxanthin (orange-red) in the fish feed is a common practice of the ornamental fish industry (Maiti *et al.*, 2017) which increased the feed cost by 10% to 20% (Bano *et al.*, 2020). In this scenario, there is a need of natural carotenoid sources for the current ornamental feed industries. Several studies reported stated that skin colouration was enhanced when fishes were cultured with natural carotenoid supplemented diets (Kaur and Shah, 2017). Different sources of natural carotenoids either plant origin such as marigold petal meal (Ezhil *et al.*, 2008; Swain *et al.*, 2014), beet and tomato powder (Mirzaee *et al.*, 2012; Singh and Kumar, 2016), carrot meal etc. (Singh and Kumar, 2016; Das, 2023) or animal-origin such as arthropods like shrimp (Pattanaik *et al.*, 2021), krill (Roncarati *et al.*, 2016), lobster (Bell *et al.*, 2019), copepod (Gümüş *et al.*, 2022), were documented in several scientific reports where these were incorporated in the diet of consumable as well as ornamental fishes and stated their positive impact on fish skin pigmentation (Bell *et al.*, 2019, Duru, 2014). Hence, formulated fish feed must contain natural carotenoid-rich ingredient supplementation that readily provide carotenoid which is requisite for their intensified target colour attainment (Gupta *et al.*, 2007).

In the developing countries, ornamental fish sector could able to contribute in economic development (Yanar *et al.*, 2008) as ornamental fish farming is a profitable activity (Besen *et al.*, 2019). To increase the profitability, there is a need to improve the productive efficiency and enhance skin coloration by the way of manipulation of their nutrition (Boonyapakdee *et al.*, 2015; Dananjaya *et al.*, 2015). Nutritional quality of fish diet has a crucial role in keeping their growth and reproductive performance, health condition, normal behaviour and in enhancement of the skin coloration of ornamental fishes (Erdogan *et al.*, 2012). Hence, growth and skin pigmentation of fish is influenced by the quality of feed and their acceptability (Sahoo *et al.*, 2010). As feed is the key factor for successful ornamental fish farming, during last few decades a wide variety of live food as well as formulated diets were tested. Among them, *Artemia* as live feed or decapsulated cysts was found to be the best choice as fishmeal alternative for several marine and freshwater fish species as *Artemia* supplementation improve their survival and growth rate (Rasdi and Qin, 2016; Prusinska *et al.*, 2020). *Artemia* commonly known as brine shrimp, a genus of aquatic crustacean, contains 50% to 60% crude protein with well-balanced amino acid profile and enriched with highly unsaturated fatty acids, vitamins and all the essential nutrients, and also some enzymes those cannot be synthesized effectively by the fishes (Abolhasani *et al.*, 2014; Rasdi and Qin, 2016; Prusinska *et al.*, 2020). Earlier reports on *Artemia* as an alternative protein source for the diet of food fish had shown satisfactory results on production performance. A few previous studies are available on ornamental fishes, feeding with *Artemia*. In most of the cases live *Artemia* nauplii was used as a starter food for their early stages. But there is a lacunae of scientific research reports where formulated diets replacing fishmeal (FM) with decapsulated *Artemia* cysts meal (DACM), was tested on ornamental fishes.

In this sense, the present feeding trial was carried out to assess and compare the effect of dietary replacement of fishmeal protein with decapsulated *Artemia* cysts protein on growth performance, food utilization, survival, whole-body composition and total carotenoid content in skin and muscle tissue of juvenile rosy barb, *Puntius conchonius*.

Materials and methods

Experimental fish and feeding trial

A six-month feeding trial was carried out in an indoor system in the Fish biology and aquaculture laboratory, Department of Zoology, Vidyasagar College, West Bengal, India. After purchasing of 500 healthy juveniles of rosy barbs from the local ornamental fish market, were kept under quarantine conditions for one week, and then acclimatized to the experimental conditions for one week in a glass aquarium (120cm×60cm×20cm) before the starting of feeding experiment. During this period, the fishes were fed with control diet. For the feeding trial, 450 juveniles with initial weight 0.21 gm to 0.24 gm, were randomly selected from the general population and divided in 5 feeding treatments each with 3 replicates in fifteen glass aquaria (120×60×45 cm) and each aquarium contains 30 fishes. The fishes were fed two times a day (09:00 and 18:00) at a rate of 6% of body weight. Uneaten feed particle and faces were siphoned out daily. Water exchange of the experimental aquaria was done at the rate of 25% in every two days interval. For maintaining the soluble oxygen throughout the experimental period, continuous aeration was given by providing compressed air with air stone in each aquarium. During the feeding trial, water quality parameters were estimated (APHA, 2005) once a week and the mean values were given as follows: water temperature at 30.67±3.70°C, pH at 7.37±0.10, dissolved oxygen at 8.18±0.15 ppm, alkalinity at 328±4.98 ppm, hardness at 625±6.32 ppm, free carbon dioxide at 1.75±0.18 ppm and total dissolved solids (TDS) at 996.5±13.41 ppm.

Experimental diets

Dried decapsulated *Artemia* cysts were purchased from a local commercial pet market and then sun-dried for 24 hours, grinded into a fine powder form and stored in an air-tight glass container until further use for preparing experimental diets for feeding trial and for the proximate nutrient analysis. Five different diets were formulated as iso-nitrogenous practical diets containing 30% crude protein. The experimental diets replaced the FM protein with the DACM protein at the levels of 0% (D0, control), 25% (D25), 50% (D50), 75% (D75), and 100% (D100) and thereby the formulated diets reduced the amount of FM by adding DACM at the inclusion level of 0%, 10.59%, 21.18%, 31.77% and 42.35% of diet respectively.

Proximate composition analysis

The proximate composition of DACM, FM, and experimental diets were analysed (AOAC, 2006) for the estimation of crude protein, crude lipid, crude fibre, ash and moisture.

Survival and growth study

After six-months of feeding trial, the number of fishes in each experimental aquarium was counted and then they were starved for 24 hours. Estimation of growth performance parameters along bioassay included: initial and final body weight, specific growth rate (SGR) [ln of final weight - ln of initial weight/total days) x 100], feed intake per fish for the experimental period, weight gain, feed conversion ratio (FCR) (feed intake (gm)/weight gain (gm)] and survival rate [(final live fish/initial live fish) × 100] (Gouveia *et al.*, 2003; Kalinowski *et al.*, 2005).

Estimation of carotenoid

At the end of the feeding trial, coloured region of skin and muscle tissue of fishes from five experimental sets were collected to determine the total carotenoid content following the method of Tiewsoh *et al.* (2019).

Statistical analysis

All the experimental data were presented in tables and figures as mean ± standard error (SE) of three replications. Data from each dietary treatment set were analyzed by one-way ANOVA and significant differences were ranked with Duncan's multiple range tests (DMRT) for multiple comparisons at the 5% level of significance.

Results

Experimental diet composition

The average proximate nutrient composition of DACM and FM used in the formulated experimental diets were tabulated in Table 1. Crude protein percentage of DACM and FM did not vary significantly (DMRT). A similar observation was noted for the estimated values of crude lipid. Crude ash and crude fibre percentage values were found slightly lower and the moisture content was higher in DACM than the values of FM (P<0.05; DMRT).

Table 1. Proximate composition of decapsulated *Artemia* cysts meal (DACM) and fishmeal (FM) (%, dry weight basis

Nutritional composition (%)	DACM	FM
Crude protein	52.00±0.73^{a}	51.00±0.88^{a}
Crude lipid	07.13±0.71^{a}	07.37±0.76^{a}
Crude ash	8.19±0.90^{a}	11.7±0.54^{b}
Crude fiber	10.30±0.65^{a}	13.27±1.21^{b}
Moisture	15.54±0.98^{b}	8.94±0.41^{a}

Values are presented as mean ± SE. Values with different superscript letters in a row denote significant differences as determined by DMRT after one way ANOVA (P<0.05)

Proportion of dietary ingredients and proximate composition of the prepared formulated diets were shown in Table 2. Crude protein (30.01-30.37%), crude lipid (11.52-12.42%), ash (10.55-11.77%) and moisture (8.55-9.64%) content of the experimental diets of rosy barbs were relatively consistent and did not vary significantly (P>0.05).

Table 2. Proportion of dietary ingredients and proximate composition of experimental diets

Diet ingredients (gm/100gm)	Diets				
	D0	D25	D50	D75	D100
FM	40.00	30.00	20.00	10.00	00.00
DACM	0.00	9.81	19.62	29.42	39.23
Soybean	6.50	6.50	6.50	6.50	6.50
Corn	3.60	4.66	5.72	6.78	7.83
MOC	5.00	5.00	5.00	5.00	5.00
Rice bran	43.60	42.73	41.86	41.00	40.14
Vitamin-Mineral Premix*	1.30	1.30	1.30	1.30	1.30
Total	100	100	100	100	100
Crude Protein	30.2±1.27^{a}	30.37±0.77^{a}	30.19±1.36^{a}	30.01±1.01^{a}	30.21±1.24^{a}
Crude lipid	11.52±1.60^{a}	11.75±1.01^{a}	11.96±1.51^{a}	12.27±1.28^{a}	12.42±1.29^{a}
Crude Fibre	4.32±0.72^{a}	5.13±1.08^{b}	6.00±1.09^{b}	7.06±1.40^{c}	8.52±1.00^{d}
Ash	10.55±1.33^{a}	10.79±1.25^{a}	11.12±1.46^{a}	11.31±1.34^{a}	11.77±1.51^{a}
Moisture	9.64±0.83^{a}	9.50±1.06^{a}	9.28±1.10^{a}	8.93±0.86^{a}	8.55±1.22^{a}

*MOC- mustard oil cake

*Vitamin-Mineral Premix (mg/kg diet): retinol-18,000 IU, Choleclaciferol-2000 IU, thiamine-15, menadione sodium bisulphate-10, riboflavin-25, pyridoxine-5, α-tocopherol-35, nicotinic acid-200, Ca-pantothenate-50, biotin-1.5, folic acid-10, cyanocobalamin-0.03, ascorbyl monophosphate-50, inositol-400, copper sulphate-20.2, dibasic calcium phosphate-5.9, sodium fluoride-2.21, potassium iodide-0.78, zinc oxide-37.5, ironsulphate-200, magnesium oxide-840, manganese oxide-26, cobalt sulphate-1.85, sodium selenite-0.65, potassium chloride-1.17, sodium chloride-0.45.

Values are presented as mean ± SE. Values with different superscript letters in a row denote significant differences as determined by DMRT after one way ANOVA (P<0.05).

Table 3. Growth parameters of rosy barb, *Puntius conchonius* fed with experimental diets in six months feeding trial

Growth parameters	Diets				
	D0	D25	D50	D75	D100
Initial weight (gm)	0.226±0.007^{a}	0.226±0.008^{a}	0.226±0.004^{a}	0.226±0.006^{a}	0.226±0.006^{a}
Final weight (gm)	1.05±0.03^{b}	1.32±0.02^{c}	1.97±0.13^{e}	1.65±0.02^{d}	0.81±0.03^{a}
Initial length (cm)	2.97±0.03^{a}	3.00±0.00^{a}	2.93±0.07^{a}	2.93±0.07^{a}	2.90±0.10^{a}
Final length (cm)	4.12±0.06^{b}	4.33±0.03^{c}	4.83±0.03^{e}	4.63±0.03^{d}	3.50±0.06^{a}
Weight gain (gm)	0.83±0.02^{b}	1.10±0.01^{c}	1.74±0.13^{e}	1.42±0.01^{d}	0.58±0.02^{a}
SGR (%)	0.85±0.01^{b}	0.98±0.01^{c}	1.20±0.03^{e}	1.10±0.01^{d}	0.71±0.01^{a}
Total food consumption (gm)	10.31±0.14^{b}	10.99±0.19^{c}	12.67±0.46^{e}	11.88±0.22^{d}	9.56±0.18^{a}
FCR	12.48±0.13^{d}	10.04±0.06^{c}	7.31±0.26^{a}	8.36±0.07^{b}	16.50±0.35^{e}

Values are presented as mean ± SE. Values with different superscript letters in a row denote significant differences as determined by DMRT after one way ANOVA (P<0.05).

Table 4. Proximate composition (%) of the whole-body of rosy barb, *P. conchonius* fed with five experimental diets in six-months feeding trial.

Nutritional Composition (%)	Diets				
	D0	D25	D50	D75	D100
Crude protein	16.25±1.23^{ns}	17.56±1.20^{ns}	17.79±1.38^{ns}	17.08±1.49^{ns}	16.28±1.47^{ns}
Crude lipid	3.53±0.0.26^{ns}	3.59±0.68^{ns}	3.79±0.56^{ns}	3.44±0.55^{ns}	3.43±0.33^{ns}
Ash	3.05±0.28^{ns}	2.72±0.40^{ns}	2.91±0.37^{ns}	2.97±0.40^{ns}	3.10±0.30^{ns}
Moisture	78.84±2.14^{ns}	79.31±3.39^{ns}	79.23±4.63^{ns}	79.33±5.16^{ns}	80.03±4.49^{ns}

Values are mean ± SE. Values with superscript ns in a row denote not significantly different (P>0.05) in one way ANOVA.

Growth performance

Growth performance and feed utilization of the experimental rosy barbs after six months feeding trial are tabulated in Table 3. A significant difference (P<0.05; DMRT) was found in final weight, weight gain, SGR (%), total food consumption and FCR of fishes fed with DACM supplemented diets and control diet. The highest (P<0.05; DMRT) growth performance and feed utilization were found at D50 when compared to other experimental diets. The estimated values of final weight, weight gain and SGR (%) were found to be highest (P<0.05; DMRT) in the fishes fed with D50 diet, followed by D75, D25, D0 (control) diet fed set and the lowest in D100 set (P<0.05; DMRT). A similar trend of result was recorded for the obtained values of total food consumption, which was significantly highest in D50 set and lowest in D100 set (P<0.05; DMRT). When considering the feed utilization parameter, it was noted that the best FCR values were obtained from the fishes fed with D50 diet and the highest value (P<0.05; DMRT) of FCR was observed from D100 set, followed by D0, D25, D75. Growth performance and feed utilization were significantly higher in the fishes fed with D50 diet, followed by D75 set and significantly lower in the fishes fed with D100 diet, followed by control set (D0).

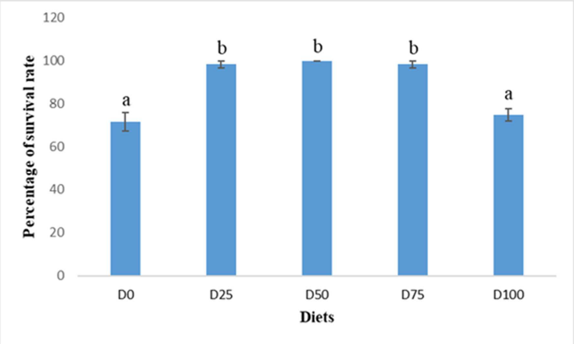

Fig. 1. Survival percent of *Puntius conchonius* fed with five different experimental diets
Values are mean ± SE. Bars with different letters are significantly different (P<0.05) using DMRT after one way ANOVA.

Survival percentage

After the six-months of feeding trial, survival of fishes fed with different experimental diets was given in Fig. 1. Supplementation of FM with DACM in the diet of rosy barbs showed a significant effect on their survival which was ranged from 65% to 100% (P<0.05; DMRT). Survival was significantly high (P<0.05) in the D25, D50 and D75 sets (DMRT), and the highest mean value was found in D50 set. Significantly low value (P<0.05) of survival was obtained from D100 and control set (D0) (DMRT).

Whole body composition

Whole body composition of the fishes fed with control and graded levels of DACM supplemented diets is given in Table 4. Dietary replacement of FM with DACM had no significant differences in whole body crude protein, lipid, ash and moisture content of the experimental rosy barbs (P>0.05).

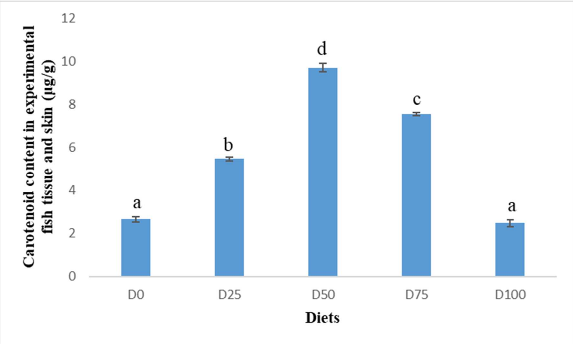

Fig. 2. Carotenoid content in fish skin and muscle tissue (µg/g)

Values are mean ± SE. Bars with different letters are significantly different (P<0.05) using DMRT after one way ANOVA.

Carotenoid concentration of rosy barb skin and muscle tissue

After six-months of feeding trial, spectrophotometric analysis of carotenoid content in the skin and muscle tissue of rosy barbs from different dietary sets is presented in Fig. 2 and the obtained values of total carotenoid content showed significant variations among the dietary sets (P<0.05; DMRT). Significantly highest (P<0.05; DMRT) amount of carotenoid was deposited in skin and muscle tissue of the fishes fed with D50 diet, followed by D75, D25. While, the value of carotenoid concentration in fish skin and muscle tissue was noted significantly low (P<0.05) in the fishes fed with D25 and D0 (control) diet (DMRT).

Discussion

Rosy barb, impressively coloured cyprinid fish species, is one of the hardiest of the barbs which has commercial importance in aquarium business (Mir and Mir, 2012; Gupta, 2015).

They are fresh water are omnivorous fish but have preference for zooplankton, mainly feed on worms, crustaceans and insects (Gupta, 2015; Allen, 2002). Fishmeal and soy products meal are commonly used protein source in commercially used nutritionally balanced fish feeds. Continuously escalating demand for fishmeal over soy protein leads to overexploitation of wild-caught fishes used as protein source in fish feed. That has paved way for consideration of every possible natural animal protein resource as a potential ingredient in fish feed. Live *Artemia* are an alternative animal protein source that are increasingly being used in aquaculture because of their nutritional quality (Conceicao *et al.*, 2010) and have significantly positive impact on fish growth. References revealed that live *Artemia* fed fishes showed improved growth performances and development (Laczyriska *et al.*, 2016; Prusinska *et al.*, 2020; Madkour *et al.*, 2023). Fresh water fishes such as climbing perch (Mahmood *et al.*, 2004), beluga (jalali *et al.*, 2008), *Poecilia latipinna* (Arulvasu and Munuswamy, 2009), tench (Celada *et al.*, 2009), Crucian carp (Demeny *et al.*, 2012), catla (Divya *et al.*, 2014), tiger barb (Abolhasani *et al.*, 2014), guppy (Suresh *et al.*, 2019), barbel (Prusinska *et al.*, 2020), goldfish (Mathew *et al.*, 2022; Alishahi *et al.*, 2015; Elshafey *et al.*, 2023), and marine fishes like *Limanda ferruginea* (Copeman *et al.*, 2002), European sea bass (El-Dahhar *et al.*, 2024) exhibited the benefit of feeding live *Artemia* on their growth efficiency and feed utilization. *Artemia* has been proven to boost the growth and performance level of red drum (Juhasz *et al.*, 2017), Atlantic sturgeon (Kamasszewski *et al.*, 2014), rainbow trout (Akbary *et al.*, 2011), Lake Sturgeon (Valentine *et al.*, 2017), green terror cichlid (Jamali *et al.*, 2018), Murray cod (Francis *et al.*, 2019), Senegalese sole larvae (Vajargah *et al.*, 2021), Pacific cod (Choi *et al.*, 2021), mandarin fish (Wang *et al.*, 2022).

Moreover, in several countries, *Artemia* used as live food in early stages of fish farming (Slembrouck *et al.*, 2009; Dhont *et al.*, 2013; Ma *et al.*, 2013, 2015). Hence, for using live *Artemia* in fish farming, there needs a continuous supply of wild caught live *Artemia* biomass or need a well-established *Artemia* culture set up with salt water as their population found in inland saltwater lake (Khadka *et al.*, 2023). Regular production of *Artemia* nauplii is challenging as it is a high labour and big-budget strategy that requires several additional facilities. Though live foods enhance the growth rate of cultured fish, but may cause endoparasites attack (Yiklmaz and Arsian, 2013). In this scenario, *Artemia* cysts might be an interesting, advantageous, acceptable alternative to live nauplii as their use as fish feed could save labour and costs. Generally, decapsulated seed were used for several freshwater fishes (Hung *et al.*, 2002; Lim *et al.*, 2002; Kaiser *et al.*, 2003; Shiri Harzevili *et al.*, 2003; Celada *et al.*, 2008) as cyst shell is nondigestible and its chemical removal does not leach nutrient, rather disinfects the cysts (Vanhaecke *et al.*, 1990). Previous studied resulted a significantly higher growth in decapsulated *Artemia* cysts fed fishes than freshly hatched nauplii such as in guppy (Lim *et al.*, 2002), goldfish (Kaiser *et al.*, 2003), tench (Celada *et al.*, 2008), etc. In this aspect, Garcia-Ortega *et al.* (1998) and Van Stappen (1996) stated that though there is no significant difference in the proximate nutrient composition between decapsulated cysts and freshly hatched nauplii, this better growth performance of fishes fed with decapsulated cysts, might be related to their energy content and dry weight, which was found 30% to 40% higher than for first instar nauplii. In contrary, Gonzalez *et al.* (2009) mentioned that *Artemia* nauplii progressively lost their nutritional quality, both when alive and after drying. To provide optimum nutrition, satisfying the nutrient requirements of ornamental fishes is prerequisite which results improved immune function and reproduction, and supports a good health and performance of natural behaviours (Cordoba, 2011). Thereby, to reach an optimum state of health and welfare, a formulated diet is indispensable for aquariculture which will supply all the essential nutrients in adequate proportion than a single ingredient (Wee *et al.*, 2021). In the present study, decapsulated *Artemia* cysts meal was incorporated in different amount replacing the traditionally used fishmeal protein and an improved growth performance and feed utilization of rosy barb was observed than the control diet having 100% fishmeal and 0% DACM, except the D100 where total fishmeal protein was replaced by DACM.

Carotenoid content in fish skin and muscle tissue depicts the level of fish skin pigmentation and the estimation of carotenoid content interprets the effect of dietary treatment on fish skin colour enhancement and also of their health condition (Kaur and Shah, 2017; Kargun and Dikbas, 2020). The highest amount of carotenoid deposition was obtained from the D50 diet fed fishes, and then in the D75 set. A similar trend was noticed for the obtained results of growth performance and feed utilization. This observation was in the line of Kargun and Dikbas (2020), where they stated that higher amount of carotenoid content in fish is an indication of their better growth performance (Kargun and Dikbas, 2020).

Keeping the above-mentioned observations in mind, DACM could be incorporated in the diet of rosy barb up to 50% replacement of fishmeal protein without compromising the growth, survival and skin pigmentation. As fish skin pigmentation is a determining factor of commercial value of ornamental fishes, the diet with 21.18% DACM, substituting 50% fishmeal protein, was recommended for the rosy barb culture.

Conclusion

From the results of the present study, it can be deduced that fishmeal replaced decapsulated *Artemia* cyst meal (DACM) incorporated diets are excellent fish feed that can fulfill the nutritional requirements of rosy barbs except the D100 diet in which fishmeal was totally replaced by DACM. Diet with 21.18% DACM, substituting 50% fishmeal protein is recommended for rosy barb, *P. conchonius* for its maximum growth performance, feed utilization, survival and skin pigmentation. However, more researches in future will seem necessary on other ornamental fishes to determine the highest inclusion level of DACM by replacing the fishmeal in their diets and these investigations will provide the species-specific inclusion level of DACM which will support maximum growth and survival, and enhanced skin pigmentation of the selected fish.

References

Abolhasani MH, Hosseini SA, Ghorbani R, Sudagar M, Hoseini SM. 2014. Growth, survival, and stress resistance of Tiger Barb (*Puntius tetrazona*) larvae fed fish oil-enriched *Artemia franciscana* nauplii. Journal of Applied Aquaculture **26**,149–156.

Akbary P, Hosseini SA, Imanpoor MR. 2011. Enrichment of *Artemia* nauplii with essential fatty acids and vitamin C: effect on rainbow trout (*Oncorhynchus mykiss*) larvae performance. Iranian Journal of Fisheries Sciences **10**, 557–569.

Alishahi M, Karamifar M, Mesbah M. 2015. Effects of astaxanthin and *Dunaliella salina* on skin carotenoids, growth performance and immune response of *Astronotus ocellatus*. Aquaculture International **23**, 1239–1248.

Allen GR., Midgley SH, Allen M. 2002. Field guide to the freshwater fishes of Australia. Western Australian Museum, Perth, Western Australia, pp: 394.

AOAC. Official methods of analysis. 18th ed. Revised. Washington, DC, USA: Association of Official Analytical Chemists, 2006.

APHA. Standard Methods for the Examination of Water and Wastewater. (21st edition), American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC, 2005.

Arulvasu C, Munuswamy N. 2009. Survival, growth and composition of *Poecilia latipinna* fry fed enriched Artemia nauplii. Current Science **96**(1), 114-119.

Bandyopadhyay P, Swain SK, Mishra S. 2005. Growth and dietary utilisation in goldfish (*Carassius auratus* Linn.) fed diets formulated with various local agro-produces. Bioresource Technology **96**(6), 731-740.

Bano F, Kashyap A, Serajuddin M. 2020. Effects of different dietary supplementation of plant carotenoids on growth, coloration and behaviour of giant gourami, *Trichogaster fasciata* (Bloch and Schneider, 1801). Iranian journal of fisheries sciences **19**(6), 2770-2789..

Bell NA, Jeffrey S, MacIsaac JL, Colombo SM. 2019. The effect of lobster meal on the growth performance and pigmentation of the common goldfish (*Carassius auratus*). Aquaculture Reports **13**(100187), 1-5.

Besen KP, Melim EWH, Cunha L, Favaretto ED, Moreira M, Fabregat TP. 2019. Lutein as a natural carotenoid source: Effect on growth, survival and skin pigmentation of goldfish juveniles (*Carassius auratus*). Aquaculture research **2**: 1–7.

Boonyapakdee A, Pootangon Y, Laudadio V, Tufarelli V. 2015. Astaxanthin extraction from golden apple snail (*Pomacea cana liculata*) eggs to enhance colours in fancy carp (*Cyprinus carpio*). Journal of Applied Animal Research, **43**, 291–294.

Çek S, Bromage N, Randall C, Rana K. 2001. Oogenesis, Hepatosomatic and Gonadosomatic Indexes, and Sex Ratio in Rosy Barb (*Puntius conchonius*). Turkish Journal of Fisheries and Aquatic Sciences **1**, 33-41.

Celada JD, Aguilera A, Garcı´a V, Carral JM, Sa´ez-Royuela M, Gonza´lez R, Gonza´lez A. 2009. Rearing juvenile tench (*Tinca tinca* L.) under controlled conditions using Artemia nauplii as supplement to a dry diet. Aquaculture International **17**, 565–570

Celada JD, García V, Carral JM, Sáez-Royuela M, González R, González Á. 2008. Larval rearing of tench (*Tinca tinca* L.) using decapsulated Artemia cysts as direct food. In: Gasco, L., Lussiana, C. (Eds.), Biologyand Culture of theTench (*Tinca tinca* L.).ISBN: 978-88-902754-1-8. Proceedings of the Fifth International Workshop, September October 2008, Ceresole d'Alba Italy. Dipartimento di Science Zootechniche, Torino, Italy, p. 5.

Chatzifotis S, Pavlidis M, Jimeno CD, Vardanis AS and Divanach P. 2005. The effect of different carotenoid sources on skin coloration of cultured red progy (*Pagrus pagrus*). Aquaculture Research **36**, 1517-1525.

Choi DH, Youn BI, Kim MJ, Lee SH, Lee SJ. 2021. Maturation and spawning of the Pacific cod *Gadus macrocephalus* in the West Coast of Yellow Sea of Korea. Korean Journal of Fisheries and Aquatic Sciences **54**, 46–52.

Conceição LEC, Yúfera M, Makridis P, Morais S, Dinis MT. 2010. Live feeds for early stages of fish rearing. Aquaculture Research **41**, 613-640.

Copeman LA, Parrish CC, Brown JA, Harel M. 2002. Effects of docosahexaenoic, eicosapentaenoic, and arachidonic acids on the early growth, survival, lipid composition and pigmentation of yellowtail flounder (*Limanda ferruginea*): A live food enrichment experiment. Aquaculture **210**(1–4), 285–304.

Córdoba MVZ. 2011. Nutritional requirements of freshwater ornamental f ish: a review. Revista Córdoba **16**, 2458–2469.

Dananjaya SHS, Munasinghe DMS, Ariyaratne HBS, Lee J, De-Zoysa M. 2015. Natural bixin as a potential carotenoid for enhancing pigmentation and colour in goldfish (*Carassius auratus*). Aquaculture Nutrition **23**, 255–263.

Das M. 2023. Effects of dietary supplementation of carrot meal on growth, survival, whole body composition and total Carotenoid Content of Zebrafish, *Danio rerio*. International journal of zoological investigations **9**(2), 575-585.

Demény F, Trenovszki MM, Sokoray-Varga S, Hegyi A, Urbányi B, Żarski D, Ács B, Miljanović B, Specziár A, Müller T. 2012. Relative Efficiencies of Artemia nauplii, Dry Food and Mixed Food Diets in İntensive Rearing of Larval Crucian Carp (*Carassius carassius* L.). Turkish Journal of Fisheries and Aquatic Sciences **12**, 693-700.

Dhont J, Dierckens K, Stttrup J, Stappen GV, Wille M, Sorgeloos P. 2013. Rotifers, Artemia and copepods as live feeds for fish larvae in aquaculture. Advances in aquaculture hatchery technology **1**, 157–202.

Divya KR, Isamma A, Arunjith TS, Sureshkumar S, Krishnakumar V. 2014. Effect of Enriched *Artemia franciscana* on Production, Survival, Growth and Biochemical Composition of the Freshwater Fish *Catla catla* (Hamilton, 1922). International Journal of Recent Biotechnology **2(3),** 15-24.

Duru M. 2014. Effects of *Spirulina platensis* added to different amounts of feed on coloring and growth performance of goldfish (*Carassius auratus*). M.Sc. thesis, Graduate School of Natural and Applied Sciences, Mersin University, p. 68.

El-Dahhar AA, Rashwan SR, EL-Zaeem SY, Shahin SA, Mourad MM, El-Basuini MF. 2024. Evaluation of the nutritional value of Artemia nauplii for European seabass (*Dicentrarchus labrax* L.) larvae. Aquaculture and Fisheries **9(2024)**, 78–84.

Elshafey AE, Khalafalla MM, Zaid AAA, Mohamed RA, Abdel-Rahim MM. 2023. Source diversity of Artemia enrichment boosts goldfish (*Carassius auratus*) performance, β-carotene content, pigmentation, immune-physiological and transcriptomic responses. Scientific Reports **13**, 21801.

Erdogan F, Erdogan M, Gümüs E. 2012. Effects of Dietary Protein and Lipid Levels on Growth Performances of Two African Cichlids (*Pseudotropheus socolofi* and *Haplochromis ahli*). Turk J Fish Aquat Sci **12**, 635-640.

Ezhil J, Jeyanthi C, Narayan M. 2008. Marigold as a carotinoid source on pigmentation and growth of red swordtail, *Xiphophorus helleri*. Turkish Journal of Fisheries and Aquatic Sciences **8**, 99-102.

Francis DS, Cleveland BJ, Jones PL, Turchini GM, Conlan JA. 2019. Effects of PUFA-enriched Artemia on the early growth and fatty acid composition of Murray cod larvae. Aquaculture **513**, 734362.

García-Ortega A, Verreth J, Coutteau P, Segner H, Huisman EA, Sorgeloos P. 1998. Biochemical and enzymatic characterization of decapsulated cysts and nauplii of the brine shrimp Artemia at different developmental stages. Aquaculture **161**, 501–514.

González R, Celada JD, Carral JM, González A, Sáez-Royuela M, García V. 2009. Decapsulated Artemia cysts as dietary supplement for juvenile crayfish (*Pacifastacus leniusculus*, Astacidae) at different food supply frequencies from the onset of exogenous feeding under controlled conditions. Aquaculture **295**(2009), 200–204.

Gouveia L, Rema P, Pereira O, Empis J. 2003. Colouring ornamental fish (*Cyprinus carpio* and *Carassius auratus*) with microalgal biomass. Aquaculture Nutrition **9,** 123-129.

Gumus E, Gurler C, Gulle I. 2022. Effect of dietary supplementation of copepod meal in goldfish *Carassius auratus* (Linnaeus, 1758) on growth performance, fatty acid profile and colouration. Indian Journal of Fisheries, **69**(1), 121-129.

Gupta S. 2015. An Overview on Food, Feeding Habit and Reproductive Biology of *Puntius conchonius* (Ham-Buch, 1822); a Freshwater Cyprinid of Indian Subcontinent. World Journal of Fish and Marine Sciences **7(3)**, 146-148

Gupta SK, Jha AK, Pal AK, Venkateshwarlu G. 2007. Use of natural carotenoids for pigmentation in fishes. Natural Product Radiance **6**(1), 46-49.

Herzog H. 2011. The impact of pets on human health and psychological well-being: fact, fiction, or hypothesis? Psychol. Sci **20**, 236-239.

Higuera-Ciapara I, Felix-Valenxuela L, Goycoolea F. 2006. Astaxanthin: a review of its chemistry and applications. Critical Reviews in Food Science and Nutrition**14**, 185–196.

Hung LT, Tuan NA, Cacot P and Lazard J. 2002. Larval rearing of the Asian catfish, *Pangasius bocourti* (Siluroidei, Pangasiidae): alternative feeds and weaning time. Aquaculture **212,** 115–127.

Jain A, Kaur VI, Hollyappa SA. 2019. Effect of dietary supplementation of carrot meal on survival, growth and pigmentation of freshwater ornamental fish, Koi Carp, *Cyprinus Carpio* (L.). Indian Journal of Animal Nutrition **36(4)**, 405-413.

Jalali MA, Hosseini SA, Imanpour MR. 2008. Effect of vitamin E and highly unsaturated fatty acid-enriched *Artemia urmiana* on growth performance, survival and stress resistance of Beluga (*Huso huso*) larvae. Aquaculture Research **39**, 1286–1291.

Jamali H, Ahmadifard N, Noori F, Agh N, Gisbert E. 2018. Improving co-feeding strategies for Neotropical green terror cichlid (*Aequidens rivulatus*) larvae with lecithin-enriched *Artemia franciscana* nauplii: Effects on survival, growth performance and body composition. Aquaculture Research **49**, 3909–3918.

Juhász P, Lengyel S, Udvari Z, Sándor AN, Stündl L. 2017. Optimised selenium enrichment of *Artemia* sp. feed to improve Red Drum (*Sciaenops ocellatus*) larvae rearing. Acta Biologica Hungarica **68**, 255–266.

Kaiser H, Endemann F, Paulet TG. 2003. A comparison of artificial and natural foods and their combinations in the rearing of goldfish, *Carassius auratus* (L.). Aquaculture Research **34**, 943–950.

Kalinowski CT, Robaina LE, Fernadez-Palacios H, Schuchardt D, Izquierdo MS. 2005. Effect of different carotenoid sources and their dietary levels on red porgy (*Pagrus pagrus*) growth and skin colour. Aquaculture **244**, 223-231.

Kamaszewski M, Wójcik M, Ostaszewska T, Kasprzak R, Kolman R, Prusińska M. 2014. The effect of essential fatty acid (EFA) enrichment of *Artemia* sp. nauplii on the enzymatic activity of Atlantic sturgeon (*Acipenser oxyrinchus* Mitchill, 1815) larvae-preliminary study. Journal of Applied Ichthyology **30**, 1256–1258.

Kargın H, Dikbaş MD. 2020. The effects of diets supplemented with *Spirulina platensis* in different quantities on pigmentation and growth performance of goldfish (*Carassius auratus*). Siberian Journal of Life Sciences and Agriculture **12(5)**, 62-78.

Kaur R, Shah TK. 2017. Role of feed additives in pigmentation of ornamental fishes. International Journal of Fisheries and Aquatic Studies **5**(2), 684–686.

Khadka N, Khadka R, Mandal RB, Adhikari A. 2023. Growth performance of live fish feed: *Artemia salina* in different supplemental feeds in aquarium culture. The Journal of Agriculture and Environment **24**, 149-155.

Łączyńska B, Palińska-Żarska K, Nowosad J, Biłas M, Krejszeff S, Müller T, Kucharczyk D, Żarski D. 2016. Effect of age, size and digestive tract development on weaning effectiveness in crucian carp, *Carassius carassius* (Linnaeus, 1758). Journal of Applied Ichthyology, **32**, 866–872.

Lim LC, Cho YL, Dhert P, Wong CC, Nelis H, Sorgeloos P. 2002. Use of decapsulated Artemia cysts in ornamental fish culture. Aquaculture Research **33**(8), 575–589.

Ma Z, Guo HY, Zhang DC, Hu CQ, Jiang SG. 2015. Food ingestion, consumption and selectivity of pompano, *Trachinotus ovatus* (Linnaeus 1758) under different rotifer densities. Aquaculture Research **46**, 2593–2603.

Ma Z, Qin JG, Hutchinson W, Chen BN. 2013. Food consumption and selectivity by larval yellowtail kingfish *Seriola lalandi* cultured at different live feed densities. Aquaculture Nutrition **19**, 523–534.

Madkour K, Dwood MAO, Sewilam H. 2023. The use of Artemia for aquaculture industry: an updated overview. Annals of Animal Science **23**(1), 3–10.

Mahmood SU, Ali MS, Anwar-Ul-Haque M. 2004. Effect of Different Feed on Larval / Fry Rearing of Climbing Perch, *Anabas testudineus* (Bloch), in Bangladesh: II. Growth and Survival. Pakistan Journal of Zoology **36**(1), 13-19.

Maiti M, Bora D, Nandeesha TL, Sahoo S, Adarsh BK, Kumar S. 2017. Effect of dietary natural carotenoid sources on colour enhancement of koi carp, *Cyprinus carpio* L. International journal of fisheries and aquatic studies **5**(4), 340-345.

Mathew RT. Debnath S, Kundu P, Alkhamis YA, Rahman MM, Rahman MM, Sarower MG, Rahman SM. 2022. Growth and survival of goldfish (*Carassius auratus*) Juveniles Fed Tubifex, custard meal and commercial feeds. The Scientific Journal of King Faisal University **23(1)**, 30-35.

Mir JI and Mir FA. 2012. Length-Weight Relationship and Condition Factor of Rosy Barb, *Puntius conchonius* (Hamilton, 1822) from River Jhelum in Kashmir Valley, India. Advances in Biological Research **6**(5), 186-190

Mirzaee S, Sabani A, Rezaee S, Hosseinzadeh M. 2012. The Effect of Synthetic and Natural Pigments on the Color of the Guppy Fish *Poecilia reticulata*. Global Veterinary **9**(2), 171-174.

Pattanaik SS, Sawant PB, Xavier MKA, Srivastava PP, Dube K, Sawant BT, Chadha NK. 2021. Dietary carotenoprotien extracted from shrimp shell waste augments growth, feed utilization, physio-metabolic responses and colouration in Oscar, *Astronotus ocellatus* (Agassiz, 1831). Aquaculture **534**, 736303e.

Prusińska M, Nowosad J, Jarmołowicz S, Mikiewicz M, Duda A, Wiszniewski G, Sikora M, Biegaj M, Samselska A, Arciuch-Rutkowska M, Targońska K, Otrocka-Domagała I, Kucharczyk D. (2020). Effect of feeding barbel larvae (*Barbus barbus* (L, 1758)) *Artemia* sp. nauplii enriched with PUFAs on their growth and survival rate, blood composition, alimentary tract his tological structure and body chemical composition. Aquaculture Reports **18**, 100492.

Rasdi NW, Qin JG. 2016. Improvement of copepod nutritional quality as live food for aquaculture: a review. Aquaculture research **47**, 1–20.

Roncarati A, Sirri F, Felici A, Stocchi L, Melotti P, Meluzzi A. 2016. Effects of dietary supplementation with krill meal on pigmentation and quality of flesh of rainbow trout (*Oncorhynchus mykiss*). Italian Journal of Animal Science **10**(2), e27.

Sahoo SK, Giri SS, Chandra S, Sahu AK. 2010. Management in seed rearing Asian catfish *Clarius batrachus*, in hatchery condition. Aquaculture Asia Magazine **15**(1), 23-25.

Shiri Harzevili A, De Charleroy D, Auwerx J, Vught I, Van Slycken J. 2003. Larval rearing of chub, *Leuciscus cephalus* (L.), using decapsulated Artemia cysts as direct food. Journal of Applied Ichthyology **19**, 123–125.

Singh RN, Kumar A. 2016. Beetroot As a carotenoid Source on growth and colour development in red swordtail *Xiphophorus helleri* Fish. Imperial Journal of Interdisciplinary Research **2**(10), 637-642.

Slembrouck J, Baras E, Subagja J, Hung LT, Legendre M. 2009. Survival, growth and food conversion of cultured larvae of *Pangasianodon hypophthalmus*, depending on feeding level, prey density and fish density. Aquaculture **294**, 52–59.

Suresh KR, Anandan P, Krishnamurthy R, Elumalai K. 2019. Formulation of flake feed using indigenous Artemia, (*Artemia franciscana*) and its effect on growth and survival of Guppy (*Poecilia reticulate*) fish. Pramana Research Journal **9(6)**, 1160-1166.

Swain H, Senapatil SR, Meshram JS, Mishra R and Murthy HS. 2014. Effect of dietary supplementation of marigold oleoresin on growth, survival and total muscle carotenoid of Koi carp, *Cyprinus carpio* L. Journal of Applied and Natural Sciences **6**(2), 430-435.

Tiewsoh W, Singh E, Nath R, Surnar SR, Priyadarshini A. 2019. Effect of carotenoid in growth and colour enhancement in Gold fish, *Carassius auratus* (l.). Journal of Experimental Zoology, India **22**(2), 765-771.

Vajargah MF, Hashemi G, Bibak M, Yalsuyi AM. 2021. The effect of vitamin C-fortified Artemia on growth and survival of *Sepia pharaonis* larvae. Journal of Environmental Treatment Techniques **9**, 815–818.

Valentine SA, Bauman JM, Scribner KT. 2017. Effects of alternative food types on body size and survival of hatchery-reared lake sturgeon larvae. North American Journal of Aquaculture **79**, 275–282.

Van Stappen G. 1996. Use of cysts, in: Lavens, P., Sorgeloos, P. (Eds.), Manual on the Production and Useof Live Foodfor Aquaculture. FAOFisheries Technical Paper 361. FAO, Rome, pp. 107–136

Vanhaecke P, De Vrieze L, Tackaert W, Sorgeloos P. 1990. The use of decapsulated cysts of the brine shrimp Artemia as direct food for carp *Cyprinus carpio* L. larvae. Journal of the World Aquaculture Society **21**(4), 257–262.

Villar-Martínez AAD, Orbe-Rogel JC, Vanegas-Espinoza PE, Quintero-Gutiérrez AG, Lara-Flores M. 2013. The effect of marigold (*Tagetes erecta*) as natural carotenoid source for the pigmentation of goldfish (*Carassius auratus* L.). Research Journal of Fisheries and Hydrobiology **8**(2), 31-37.

Wang YY, Liang XF, He S, Tang SL, Peng D. 2022. The potential use of Artemia for larval rearing of mandarin fish (*Siniperca chuatsi*). Aquaculture Reports **25**(2022), 101216.

Wee S, Loong S, Ng NS, Cabana F. 2021. Artemia as a sustainably cultured live feed for ornamental fish in zoological institutions with immunostimulant properties when bioencapsulated with spirulina *Arthrospria platensis*. Journal of Zoo and Aquarium Research **9**(2), 110-115.

Yanar M, Erçen Z, Hunt A, Büyükçapar HM. 2008. The use of alfafa, *Mendicago sativa* as natural carotenoid source in diets of goldfish, *Carassius auratus*. Aquaculture **284**, 196-200.

Yiklmaz A, Arsian D. 2013. Oscar (*Astronotus ocellatus* Agassiz, 1831) rearing. Türk Bilimsel Derlemeler Dergisi **6**, 51-55.