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Original Article

Impacts of palmyrah (*Borassus flabellifer*) fruit pulp-enriched diets on growth and colouration of swordtail (*Xipophorus helleri*) and platyfish (*Xipophorus maculatus*)

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Abstract
The ornamental fish industry urgently needs natural carotenoid sources due to the undesirable effects of synthetic additives. This study examines the effects of an untapped carotenoid source, palmyrah fruit pulp (PFP), on the growth and skin colour of swordtails (*Xipophorus helleri*) and platies (*Xipophorus maculatus*). Experimental diets containing 40% crude protein were formulated with varying PFP levels (%) at 0, 3, 6, and 8. A commercial diet was used as a positive control, while a diet without PFP was a negative control. Four-week-old swordtails (*n*=450) and platies (*n*=450) were divided into 15 groups for five treatments, and all were kept under the same conditions. The experiment lasted 81 days for the swordtail and 83 days for the platy. The findings show that the 8% PFP diet led to a significant increase in the skin colour in both fish compared to the other treatments. Higher growth performance (ANOVA: $p<0.001$) was observed in both fish when fed 3, 6, and 8% PFP diets compared to the negative control group; however, no significant difference from the positive control group. All treated groups had a survival rate of over 92%, and weight gains followed strong polynomial relationships ($R^2>0.98$). The study concludes that an 8% PFP-enriched diet effectively influenced skin colour, with TCC levels of 85.59 µg g^{-1} in swordtails and 80.54 µg g^{-1} in platies. Furthermore, this diet promotes the growth of swordtails and platies. This diet serves as an adequate substitute for commercial fish feeds in the ornamental fish industry.

Keywords: aqua feed; natural carotenoid; ornamental fish

1 | INTRODUCTION

The vibrant colours and growth performance of ornamental fish play crucial roles in determining their commercial value and popularity within the aquarist community (Jones *et al.* 2022). These attributes are not merely aesthetic; they directly correlate with the health and vitality of the fish. To achieve and sustain their vivid skin coloration, ornamental fish require dietary carotenoids, which can be obtained from natural and synthetic sources (Pereira da Costa and Campos Miranda-Filho 2020). However, the preference for natural carotenoids is widely acknowledged, as synthetic alternatives may negatively impact the culture system, adversely affecting water quality and fish well-being (Mussagy *et al.* 2022). Aquaculturists cannot only enhance fish health and appeal but also reduce their carbon footprint by utilising natural feed additives sourced from local suppliers. This approach fosters sustainability within the aquaculture sector and bolsters the national economy. Adopting such innovative dietary formulations could serve as a sustainable and effective strategy for aquaculture, leading to improved aesthetic appeal, health, and overall growth performance of the fish (Sarker 2023).

Researchers have made significant strides in investigating the application of natural feed colour additives such as natural bixin for goldfish (Dananjaya *et al.* 2017), papaya peel extracts for guppy (Rodrigo and Perera 2018), marigold petals and banana peel for koi carp (Sachintha *et al.* 2020), herbal supplements (garlic, red onion, and sweet red pepper) for guppy (Champika Perera *et al.* 2024; Mousavi *et al.* 2024). However, despite these advancements, there exists a substantial gap in the exploration and utilization of alternative natural colour sources available in our environment. Many potential resources that could be effective as feed additives remain under-researched or entirely overlooked. This presents an opportunity to expand the current knowledge base by identifying and characterising these untapped resources, assessing their efficacy and safety as additives, and integrating them into existing feed formulations (Sathyaruban *et al.* 2021). Addressing this gap could lead to more sustainable and cost-effective solutions in animal nutrition, ultimately benefiting both livestock producers and consumers.

One promising source is palmyrah fruit pulp (PFP; *Borassus flabellifer* L.), which has garnered attention for its numerous health benefits and nutrient-rich profile (Priyadarshani and Jansz 2014). This pulp is packed with essential vitamins, minerals, and antioxidants that are thought to significantly enhance fish physiology and colouration, offering a potential avenue for enriching the diets of ornamental fish and improving their overall vitality.

Palmyrah fruit has yet to be explored in the ornamental fish feed. However, a recent study has explored the use of PFP as a natural carotenoid source in aquaculture, especially in ornamental fish farming. Sathyaruban *et al.* (2024) investigated the impact of PFP-enriched diets on the growth and coloration of guppies. The study revealed that diets incorporating PFP significantly improved skin coloration and growth performance while maintaining high survival rates among fish. The findings underscore the potential of PFP as a sustainable alternative to synthetic carotenoid sources in aquafeed, contributing to the improved aesthetics and health of ornamental fish.

The utilisation of PFP encapsulates significant potential for promoting environmental sustainability. By integrating PFP in aquaculture and agriculture, researchers advocate for a reduction in reliance on synthetic additives, which can adversely impact ecosystems. The swordtail (*Xipophorus helleri*) and platyfish (*Xipophorus maculatus*) are two species that have gained immense popularity among aquarium enthusiasts due to their vibrant colours and exceptional hardiness. These attributes not only make them visually appealing but also contribute to their resilience in varying aquatic environments, which is why they are regarded as staples in exporting (Novák *et al.* 2020). This growing interest in diet optimization reflects a broader trend within the aquaculture industry, where the intersection of nutrition and aesthetics is recognized as crucial for cultivating fish that are not only beautiful but also robust and thriving in captivity. This research aims to investigate the effects of experimental diets enriched with PFP, on these two species' skin colouration and growth performance.

2 | METHODOLOGY

2.1 Fish samples

Four-week-old red swordtail (n = 450) and platyfish (apple Mickey mouse strain; n = 450) were purchased from the National Aquaculture Development Authority (NAQDA) ornamental fish breeding centre, Rambodagalla, Sri Lanka. They were acclimatised for a week in indoor aquaria in the wet laboratory at the Department of Fisheries, University of Jaffna, Sri Lanka.

2.2 Experimental setup

Fifteen glass tanks, each measuring 107.5 cm in length, 46.5 cm in width, and 46.5 cm in height, were filled with fresh water to a volume of 75 – 80 L to provide a suitable habitat for the fish. An internal filtration system, a sponge filter from Xinyou, China, was installed in each tank, and a 385 W HAILEA air compressor from China was used to aerate all the tanks. The photoperiod was set to 12 h of light and 12 h of darkness during the experiment. The experiment consisted of five treatments with three replicates, including a positive control (commercial diet) and a negative control (diet without PFP).

2.3 Water quality parameters

Water quality parameters were kept within recommended ranges: water temperature (26.95 ± 0.47 °C), dissolved oxygen (9.01 ± 0.32 mg L^{-1}), pH (8.13 ± 0.09), salinity (0.46 ± 0.04 ppt), total ammonia nitrogen (1.02 ± 0.40 mg L^{-1}), and nitrate (0.154 ± 0.08 mg L^{-1}). The photoperiod was set to 12 h light: 12 h dark with fluorescent lights. Parameters were measured with standard equipment regularly. Water temperature, dissolved oxygen, and pH were assessed weekly with a thermometer, oxygen meter (Lovibond, Germany), and pH meter (Lovibond, Germany). Ammonia and nitrite levels were checked fortnightly using a UV-Vis spectrophotometer (Hach DR/4000U, USA) (Othman *et al.* 2014). Tanks were cleaned and water was changed weekly.

2.4 Carotenoid source

Ripe palmyrah (*Borassus flabellifer* L.) fruits were collected from Northern Province, Sri Lanka. The collected fruits were immediately kept in a Styrofoam box and brought to the laboratory. They were cleaned and labelled. The extracted pulp was used for feed preparation. The chemical composition and total carotenoid content of the PFP were tested at the Ceylon Grain Elevators PLC (Prima Group—Sri Lanka) using the standard methods of AOAC (2019) and a UV-VIS spectrophotometer according to the protocol described by Torrissen and Naevdal (1988).

2.5 Experimental feeds

Four isonitrogenous (40.23 ± 0.17% dry weight crude protein) and isoenergetic (17.54 ± 4.4 KJ g^{-1}) experimental diets were formulated using a linear programming model as shown in Table 1 and designed as follows:

FPal-0-Diet without PFP (negative control diet)
FPal-3-Diet supplemented with 3% PFP
FPal-6-Diet supplemented with 6% PFP
FPal-8-Diet supplemented with 8% PFP
Com- Commercial diet (positive control diet, which was purchased in the Market)

The dry feed pellets with similar dimensions were processed in the machine (pellet mill machine, China).

TABLE 1 Formulation of the experimental diets for swordtail and platy fishes.

Raw ingredient ($g\ kg^{-1}$ dry weight)	FPal-0	FPal-3	FPal-6	FPal-8
Fish meal	28.0	29.0	29.0	29.0
Soybean meal	40.0	40.0	40.0	40.0
Maize	13.0	11.0	9.0	8.0
PFP	0.0	3.0	6.0	8.0
Fish oil	2.0	2.0	2.0	2.0
Vitamin-mineral mixture	2.0	2.0	2.0	2.0
DL-methionine	2.0	2.0	2.0	2.0
L-lysine	0.1	0.1	0.1	0.1
Di-calcium phosphate	0.1	0.1	0.1	0.1
DL-methionine	0.5	0.5	0.5	0.5
Wheat flour	12.3	10.3	9.3	8.3

Composition of vitamin-mineral mixture per 1 kg- vitamin A-1000,000 IU, vitamin D3- 100,000 IU, vitamin E- 10,000 IU, vitamin C- 10,000 mg, vitamin K- 800 mg, vitamin B1–1500 mg, vitamin B2–1200 mg, vitamin B6–750 mg, vitamin B12–20 mg, pantothenic acid- 3000 mg, niacin- 2150 mg, folic acid- 300 mg, Inositol – 25,000 mg, biotin- 25 mg, selenium- 30 mg, iron- 20,000 mg, zinc- 32,000 mg, copper- 2000 mg, cobalt- 150 mg, iodine- 325 mg, magnesium- 6000 mg, potassium100 mg, sodium- 5.9 mg, manganese- 1500 mg.

2.6 Stocking

A total of 30 swordtail fish (mean body weight of 676 ± 18 mg) and 30 platyfish (mean body weight 355 ± 6 mg) were randomly stocked separately in each tank. Fish were randomly assigned to the tank by physically shuffling a list of five fish and distributing them sequentially into the tank until each tank contained 30 fish. All the fish were fed a commercial diet for the first week. The body weight (to the nearest 0.001 g) of the randomly selected ten fish in each treatment was measured after the first week of rearing using OHAUS PIONEER PA 214 C chemical balance (OHAUS Corporation, Parsippany, USA).

2.7 Feeding

For the first month, the fish were hand-fed ad libitum to visual satiation (7% of the body weight) thrice a day at 9:00, 13:30, and 17:00 h. After that, the satiation time was changed twice daily to 9:00 and 17:00 h.

2.8 Analysis of Total Carotenoid Content (TCC) of fish

After the experiment, which lasted 81 days for swordtail and 83 days for platy fish, was completed, a random sample of five to six fish was taken from each tank. The extraction of carotenoids from the minced homogenized fish skin was performed using a UV-VIS Spectrophotometer according to the method described by Torrissen and Naevdal (1988). The absorption of the cooled supernatant was measured against the blank at 450, 470, 500, and 540 nm by Spectrophotometer (UV-VIS) (Hach DR/4000U Spectrophotometer, USA) against the blank. The wavelength at maximum absorption was used for the calculation.

$$= [\text{Absorption} \times \text{dilution factor}] / [A_{1cm}^{1\%} \times \text{Sample weight (g)}]$$

Where, $A_{1cm}^{1\%}$ = Extinction coefficient (0.25)

2.9 Analysis of biological indices

The fish were taken from each tank to evaluate their growth performance and Survival rate using the following formula (Gouveia *et al.* 2003; Kalinowski *et al.* 2005).

Survival rate = (Final fish number / Initial fish number) × 100.
Weight gain (WG) = Final weight (g) – Initial weight (g).
Daily weight gain (DWG) = Weight gain (g) / Number of days.
Relative weight gain (RWG = Weight gain (g) / Initial weight (g) × 100.
Specific growth rate (SGR) = (Ln weight (final) – Ln weight (initial)) / number of days × 100.

2.10 Data analysis

All the measurements were repeated in triplicate. Data on survival rate, growth performance (weight gain, relative weight gain, daily weight gain, and specific growth rate), and total carotenoid content were processed and compiled using MS Excel. Statistical analysis was completed using R Statistical Software (R Core Team 2023). All data were tested for normality and homogeneity of variance. Differences among groups were determined by one-way ANOVA or non-parametric statistics (Kruskal Wallis). Tukey significant means test was employed to identify groups that were significantly different. Statistical differences were considered when $p < 0.05$. In addition, linear and quadratic regression analyses were done to derive the relationship of the growth of fish with the experimental days.

3 | RESULTS

3.1 total carotenoid content (TCC) of the skin

In this study, the addition of PFP to the fish diet significantly impacted the skin colouration of both species compared to the negative control groups (Figure 1). Both fish species fed the FPal8 diet accumulated the highest TCC value compared to other groups; however, the colour concentration showed significant differences between them. There was a marked decrease in carotenoid levels for both species fed with FPal-3, with the gap between the two fish types widening. In this case, the carotenoid content is minimal, reflecting a significant reduction from the previous feeds. Across all feed types, platyfish generally maintain a higher total carotenoid content compared to swordtail fish. The result suggests that FPal-8 and commercial feeds provide the best carotenoid levels for both fish species, with FPal-0 yielding the least beneficial results regarding carotenoid content.

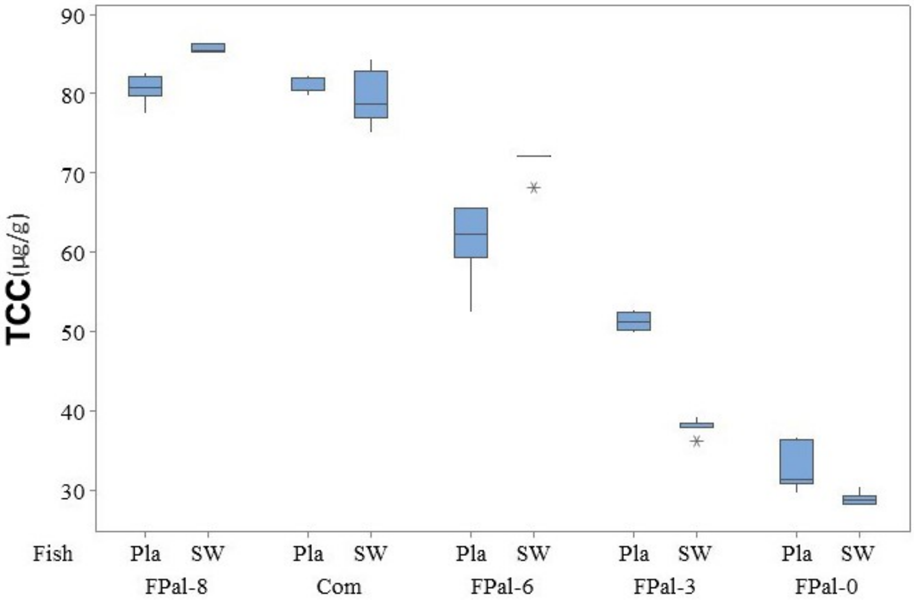

FIGURE 1 Total carotenoid content (mean) of the two fish skin. The mean values of the fish respected with the feed types with a number of asterisk (*) are significantly different (Kruskal-Wallis test: $p < 0.05$). SW, Swordtail; Pla, Platyfish. FPal-0, diet without PFP (negative control diet); FPal-3, diet supplemented with 3% PFP; FPal-6-Diet supplemented with 6% PFP; FPal-8, diet supplemented with 8% PFP; Com-commercial diet (positive control diet).

3.2 Growth performance

Table 2 summarise the growth performance of the fish groups. The outcomes of this study revealed no significant difference ($p > 0.05$) in the initial weight of fish treatments across the fish groups. However, the weight of fish in each group increased over time, and some groups showed significant differences in weight at the end of the experiment.

Swordtail fish on the FPal-8 and Com diets had the highest final weight, weight gain, specific growth rate (SGR), and survival rate. Although the fish's weight increased over time, there was no significant difference (ANOVA: $p > 0.05$) in final weights among those fed FPal-6, FPal-8, and Com. Fish on the FPal-8 diet gained more weight than others, but not significantly more than those on the commercial diet. The lowest weight gain occurred in the negative control group (FPal-0). A significantly higher relative weight gain (RWG) was recorded for the Fpal-8 group compared to others. The SGR for fish on FPal-0, FPal-3, and FPal-6 differed significantly, while SGR values for FPal-8 and Com were higher than the other three groups. The FPal-0 group had the lowest SGR and daily growth rate (DGR), whereas those on FPal-8 had the highest weight gain, similar to the Com group. The results of the platyfish growth show that the experimental diets enriched with PFP at various levels positively impact the growth of the platy compared to the group-fed diet without PFP. It was observed that including PFP in the diet at levels greater than 3% significantly improved the growth performance of the platyfish. This suggests that an experimental diet enriched with PFP can be utilised in fish feed instead of a commercial diet for swordtail.

There are no significant differences in the survival rate of both fish groups. These results suggest that the FPal-8 and Com diets are more effective in promoting fish growth and survival than other diets. The weight gains during this timeframe followed a polynomial relationship, with R^2 values for all treatments exceeding 99% (Figure 2). A positive trend was evident in the data, indicating that the rate of weight gain for swordtails was higher than that of platyfish.

TABLE 2 Growth performances of swordtail fish and Platyfish.

Parameters	Swordtail					Platyfish				
	FPal-0	FPal-3	FPal-6	FPal-8	Com	FPal-0	FPal-3	FPal-6	FPal-8	Com
Initial weight (mg)	686 ± 18	681 ± 16	680 ± 4	657 ± 22	676 ± 6	348	350 ± 4	359 ± 5	358	359 ± 1
Final weight (mg)	2679 ± 94	2827 ± 69	2896 ± 31	2937 ± 64	3009 ± 138	1685 ± 25[c]	1713± 39[b]	1784 ± 18[a]	1792 ± 41[a]	1793 ± 27[a]
WG (mg fish^{-1})	1993 ± 87[d]	2146 ± 70[c]	2216 ± 31[b]	2279 ± 74[a]	2268 ± 89[a,b]	1337 ± 25[c]	1363 ± 39[b]	1425 ± 19[a]	1433 ± 41[a]	1433 ± 27[a]
RWG (%)	235.23 ± 10.51[d]	255.43 ± 11.77[c]	263.70 ± 4.1[b]	281.40 ± 16.81[a]	271.69 ± 10.64[b]	383.81 ± 7.52[b]	388.84 ± 12.69[b]	396.54 ± 8.95[a]	399.37 ± 11.54[a]	398.72 ± 8.06[a]
SGR	1.68 ± 0.04[d]	1.75± 0.04[c]	1.78 ± 0.01[b]	1.84 ± 0.05[a]	1.81 ± 0.03[b]	1.85 ± 0.01[b]	1.86 ± 0.03[b]	1.88 ± 0.02[a]	1.89 ± 0.02[a]	1.89 ± 0.01[a]
DGR (mg fish^{-1})	24.6[d]	26.4[c]	27.3[b]	28.1[a]	28[a,b]	15.7[c]	16[b]	16.7[a]	16.8[a]	16.8l[a]
Survival rate	93.22 ± 0.5	93.55 ± 0.38	93.11 ± 0.19	93.77 ± 0.19	93.66 ± 0.33	93.11 ± 0.19[c]	94.33 ± 0.57[a,b,c]	93.33 ± 0.33[b,c]	95.22 ± 0.5[a]	94.55 ± 0.83[a,b]

Values are means of triplicate groups and presented as mean ± SD. Values in the same row with different superscript letters of each fish differ significantly ($p < 0.05$). The lack of superscript letters indicates no significant differences among treatments. FPal-0, diet without PFP (negative control diet); FPal-3, diet supplemented with 3% PFP; FPal-6-Diet supplemented with 6% PFP; FPal-8, diet supplemented with 8% PFP; Com- commercial diet (positive control diet).

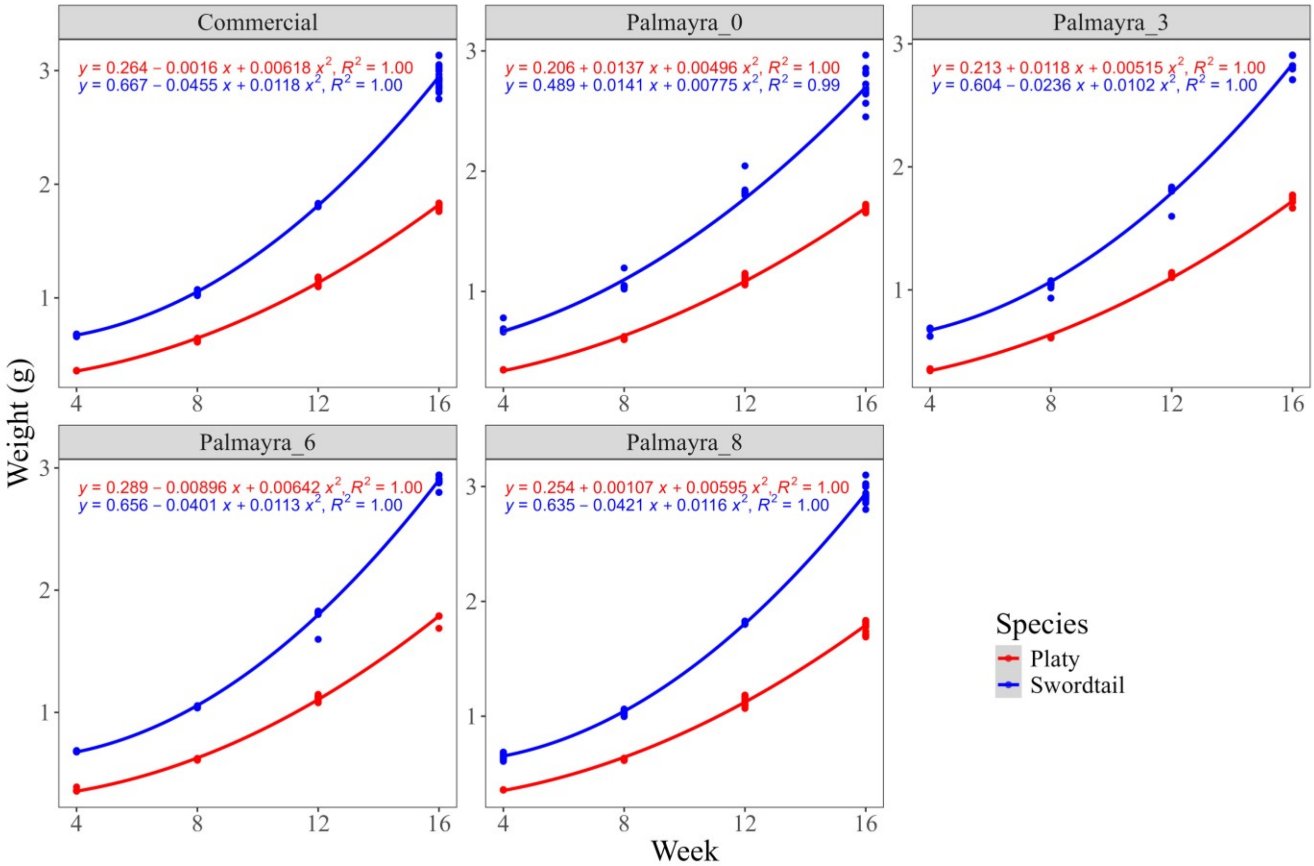

FIGURE 2 Growth curves of swordtail and platyfish fed with experimental and commercial diets during weeks 4 to 16. A, fish fed com; B, fish fed FPal-0; C, fish fed FPal-3; D, fish fed FPal-6; E, fish fed FPal-8. FPal-0, diet without PFP (negative control diet); FPal-3, diet supplemented with 3% PFP; FPal-6-Diet supplemented with 6% PFP; FPal-8, diet supplemented with 8% PFP; Com- commercial diet (positive control diet).

4 | DISCUSSION

The research findings indicated that the PFP positively affected the skin colouration and growth performance (WG, RWG, SGR, and DGR) of both fish at the end of the experiment. However, the amount of pigmentation varied among the different species. The tested colour additive source contains sufficient amounts of carotenoids to create adequate skin pigmentation.

The findings of the study demonstrate that increasing the levels of PFP in both fish diets leads to a proportional rise in the total carotenoid content in their skin. Notably, fish-fed experimental diets enriched with PFP and commercial diets exhibited significantly higher total carotenoid content than those fed with the control diet (without PFP). This unequivocally indicates that PFP substantially impacts the skin colouration of swordtail and platyfish. Additionally, the higher total carotenoid content in platies compared to swordtails may result from various internal and external factors such as carotenoid extraction methods, genetic factors, and carotenoid metabolism (Sathyaruban *et al.* 2021). There is no standard pathway for the metabolism and transformation of carotenoids across all fish tissues (Liao *et al.* 2025). Previous records have focused on carotenoid metabolisms in livebearers, but there have been limited studies on other ornamental fish. For instance, carp and goldfish can absorb zeaxanthin pigment from their diets, accumulate and metabolise into astaxanthin pigment through 4-ketozeaxanthin (Simpson and Chichester 1981; Liu *et al.* 2024). Additionally, carotenoid metabolism has been documented in food fish, such as trout (Katsuyama *et al.* 1987) and salmon (Schmeisser *et al.* 2021).

In the present study, the optimal inclusion level for swordtails and platies is 8% PFP. The maximum limit of colour feed additives for ornamental fish may vary depending on the specific additive used, as well as regulatory guidelines set by different countries or organisations (Bai *et al.* 2015). However, it is recommended that natural carotenoid sources, such as those derived from plants, be incorporated into the diet at a range of 1% to 8% (Barad *et al.* 2024). However, more specific limits can depend on factors such as the species of fish, the intended outcome in terms of coloration, and the formulation of the feed. Elevated levels of herbal additives can result in more noticeable pigmentation, while lower levels tend to produce gentler hues (Unver and Hamzaçebi 2020). Therefore, it is crucial to accurately establish the right dosage of herbal additives to attain the intended pigmentation without adversely affecting the fish.

No literature addresses TCC analysis of swordtail fish with PFP as a dietary additive. However, this study aligns with Nasrollahzadeh and Allaf (2014), who observed that adding red pepper (*Capsicum annum*) at 4% and 6% made swordtail fish (*X. helleri*) bright red, significantly differing from other diets.

While studies on PFP's role in enhancing platy carotenoids are scarce, Das (2023) noted a TCC enhancement of 9.23 ± 0.071 µg g^{-1} in platy fed mealworm-enriched diets. Abdollahi *et al.* (2019) found significant skin colour changes in platies given β-carotene-enriched *Artemia franciscana*, with a peak TCC of 112.4 ± 22.79 µg g^{-1} compared to 24.31 ± 2.26 µg g^{-1} in unenriched diets.

The present study's growth analysis confirmed that PFP significantly influences the growth of both swordtails and platies. The inclusion of PFP at levels greater than 3% in the diet significantly improved growth performance in both types of fish. The diet (> 3% PFP) had a higher nutritional profile with optimum protein and energy, providing essential nutrients for growth. In contrast, commercial diet also supported satisfactory growth in both species. However, there was no significant difference observed among the diets with varying levels of palmyrah inclusion. Notably, the FPal-0 group (lack of PFP) demonstrated reduced growth performance, emphasizing the inadequate nutrient intake can lead to poorer growth outcomes. This observation underscores the importance of maintaining a well-balanced diet for optimal fish growth. Swordtails and platies have differing nutritional needs based on their biology and metabolic rates (Velasco-Santamaría and Corredor-Santamaría 2011). These variations can affect how each species utilizes the nutrients in their diets, leading to differences in growth performance.

Only Sathyaruban *et al.* (2024) examined the PFP's effect on guppy growth. Few studies on swordtail and platy growth with various additives exist. Monica *et al.* (2021) reported no significant growth effects when 400 mg kg^{-1} anthocyanin powder from beetroot peel and red cabbage was used as an additive for orange swordtail fish (*X. helleri*). Rana *et al.* (2023) found that carrots did not positively impact swordtail fish growth. Similarly, Rintan *et al.* (2019) reported no growth benefits for swordtails from butterfly pea leaf meal (*Clitoria ternatea*). Das (2023) studied platy growth using non-conventional insects (cricket, grasshopper, and mealworm), finding that insect-enriched feed positively affected growth.

The survival rates of both fish were similar when fed different PFP at various inclusion levels. Thus, the present study confirms that survival is less likely to be affected by PFP inclusion levels in juvenile fish. No literature data is available on the survival rate of swordtail fish using fruits. However, in a study by Das (2023), the survival rate of swordtails was investigated when fed on three non-conventional insects and a commercial diet. The author concluded that the mean survival percentage was 90% in the mealworm diet, and the lowest survival value was 55% in the commercial diet. Nonetheless, in the present study, there is no significant difference in the survival rate of the swordtail fish between the commercial and experimental diet groups. Two more studies were conducted to assess the survival rate of swordtail fish using microalgae

(Sipaúba-Tavares *et al.* 2019) and astaxanthin (Putra *et al.* 2020). These two feed additives were found to influence the survival rate of the swordtail fish.

The use of PFP in aquaculture has garnered attention due to its sustainability and economic relevance compared to synthetic additives. Palmyrah fruit is derived from renewable plant sources, making it a more environmentally friendly option than synthetic additives, which are often petroleum-based and can contribute to pollution and resource depletion (Sathyaruban *et al.* 2021).

Further, natural additives tend to support biodiversity and promote healthier water systems. While the initial costs for sourcing PFP may be higher than those of synthetic additives, the long-term savings from improved fish health, growth rates, and lower mortality can offset these costs (Sutharshiny *et al.* 2022).

5 | CONCLUSIONS

The present study demonstrates the promising potential for using PFP as a carotenoid source in two fish species, swordtail and platy. Increasing the PFP in the swordtail and platyfish diet enhanced skin carotenoid content, leading to significant colouration improvements. The best skin colouration for swordtail and platyfish was achieved with the FPal-8 diet, which contained 8% PFP. In addition, swordtail and platyfish showed higher growth performance when fed with the experimental feed (Fpal-8) compared to other diets. The weight gains of the fish showed a polynomial relationship with R^2 values above 99.3% for all treatments. Overall, the results of the present study suggest that a locally formulated diet enriched with PFP can be an effective alternative to commercial fish feeds, potentially benefiting both fish farmers and fish populations.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

AUTHORS' CONTRIBUTION

Sutharshiny Sathyaruban: conceptualisation, methodology, investigation, data curation, formal analysis, investigation, writing the original draft, funding acquisition, project administration. Deepthi Inoka Uluwaduge: conceptualisation, supervising, validation, editing the draft. Sivashanthini Kuganathan: conceptualisation, supervising, validation, editing the draft manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on a reasonable request from the corresponding author.

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