Adaptive habituation and assessing the feeding effect on growth performance and body composition of an aquarium fish red swordtail, *Xiphophorus hellerii* (Heckel, 1848) in Bangladesh

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INTRODUCTION

The rearing of ornamental piscine organisms is one of the important economic and profitable fish farming activities in Asian countries (Absali & Mohamad, 2010).
colorful and attractive characteristics of ornamental fishes are gaining prominence in aquaculture because of their aesthetic and enormous commercial value in the export and trade around the world (Wagde et al., 2018). The red swordtail (Xiphophorus helleri), a benthopelagic colourful fish usually inhabits fresh and brackish water habitat, is considered a very popular ornamental fish species due to the variety of body colors and fin patterns (Ling et al., 2006). It is one of the prettiest fish for an aquarium and is a very hardy species (Ghosh et al., 2007). The culture of green swordtail is concentrated in Indonesia, Malaysia, Thailand, Singapore, India, and China in floating net cages or in earthen ponds (Radhika et al., 2007). Ornamental fish are mostly fed with live feed which consists of zooplankton and phytoplankton (Anjur, 2017). The commercial producer of ornamental fish is demanded to supplement formulated feeds with live feed, which is very important for growth improvement (Lim et al., 2003). Live feeds are responsible for introducing harmful pathogens and may not provide adequate nutrition for broodstock fish (Shu-Chien et al., 2004). Thus, the development of formulated feed is necessary for the growth of ornamental fish, especially red swordtail fish.

Feed composition, quality and quantity, and ration size are among the most important factors that have profound effects on growth performance, gonad development, reproduction, and whole-body composition of fish (Sampath & Pandian, 1984; James et al., 1993). The nutritional content explicitly protein, fat, vitamins, and minerals are required for egg development and spawning of female fish (James et al., 2006). Dietary protein and lipids are major sources of metabolic energy during the embryonic and pre-feeding larval stages in fishes (Mousavi-Sabet et al., 2013). On the other hand, formulated feed and its nutritional composition are important for feed conversion and quicker growth in farmed ornamental fish (Wagde et al., 2018). There are several reports on the effect of different forms of feed on the growth, survival and reproduction of ornamental fishes (James & Sampath, 2004; Shu-Chien et al., 2004; Anka et al., 2016; Kradal et al., 2018). In addition, the growth and reproductive performances of live breeders including swordtails are influenced by the nutritional composition of feed (Dzikowski et al., 2001; Ling et al., 2006). Consequently, the study of feed supplementation is an important parameter for the rearing the red swordtail, X. helleri.

In Bangladesh, different types of commercial feeds are used for rearing ornamental fishes, and protein content ranged from 30-32%. A commercial diet (mega feed) containing 34.11% protein increases the growth of goldfish (Shajib et al., 2017). Anka et al. (2016) found that formulated feed gives better growth in the guppy Poecilia reticulata (Peters, 1859) than the commercial pelleted feed. Although several studies have evidence that various types of feed influence growth performance, yet the studies on the body composition of ornamental fishes in Bangladesh are scarce. In the Bangladesh context, very little information is available on the nutritional requirements of red swordtails for better growth efficiency in aquarium conditions. Moreover, studies assessing the effects of feed on the growth performance and body composition of red swordtail, X. helleri are extremely scant in Bangladesh. In this regard, the present research aimed at assessing the habituation efficiency, growth performance, and body composition of red swordtail X. helleri.
MATERIALS AND METHODS

1. Experimental settings, diets preparation and test fish

Initially, 9 glass aquaria with a capacity of 105 liters were prepared at the laboratory of aquaculture, Sylhet Agricultural University (SAU), Sylhet, Bangladesh. After preparing the aquarium, it was confirmed that it is leakproof by filling it with water. Then, two filters and two air-stones were set in each aquarium to provide filtration and sufficient aeration during the experimental period. Rock stones were introduced into every aquarium and filled the aquarium with clean water. All aquaria were kept on a 1m high concrete platform to facilitate better observation and accessibility. Complete randomized design (CRD) was used for the experiment and the study design contained three treatments (T₁, T₂, and T₃) and each with 3 replications (R₁, R₂ and R₃) (Table 1).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Replication</th>
<th>Stocking density per aquaria</th>
<th>Fed with the experimental diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁</td>
<td>R₁</td>
<td>20</td>
<td>Diet 1 (formulated feed)</td>
</tr>
<tr>
<td>T₁</td>
<td>R₂</td>
<td>20</td>
<td>Diet 1 (formulated feed)</td>
</tr>
<tr>
<td>T₁</td>
<td>R₃</td>
<td>20</td>
<td>Diet 1 (formulated feed)</td>
</tr>
<tr>
<td>T₁</td>
<td>R₄</td>
<td>20</td>
<td>Diet 2 (Mega feed)</td>
</tr>
<tr>
<td>T₂</td>
<td>R₂</td>
<td>20</td>
<td>Diet 2 (Mega feed)</td>
</tr>
<tr>
<td>T₂</td>
<td>R₃</td>
<td>20</td>
<td>Diet 2 (Mega feed)</td>
</tr>
<tr>
<td>T₂</td>
<td>R₄</td>
<td>20</td>
<td>Diet 3 (Fast red feed)</td>
</tr>
<tr>
<td>T₃</td>
<td>R₂</td>
<td>20</td>
<td>Diet 3 (Fast red feed)</td>
</tr>
<tr>
<td>T₃</td>
<td>R₃</td>
<td>20</td>
<td>Diet 3 (Fast red feed)</td>
</tr>
</tbody>
</table>

2. Stocking and post-stocking feeding regimes

Three feeds were selected for the experiment. Diet 1 was formulated feed, which was prepared with basic ingredients explicitly 16% of rice bran, 48% of fish meal, 30% of mustard oil cake, 4% of molasses, and 2% of vitamin and mineral premix at Aquaculture Laboratory, Faculty of Fisheries, Sylhet Agricultural University (SAU). The other two commercial feeds were mega feed and fast red feed and coded as diet 2 and diet 3, respectively. Finally, diets were air dried and stored in air-tight containers until fed to fish. The proximate compositions of the test diets were determined according to the standard procedure of AOAC (2000) (Table 2).

The freshwater red swordtail, X. hellerii, fries were purchased from “Love and Hobby World”, a commercial ornamental fish selling shop located at Zindabazar, Sylhet, Bangladesh. Healthy fish fries, with an average body weight of “0.05±0.001g” and length “1.68±0.016cm” were collected, transported to the laboratory, and randomly stocked @ 20 fishes per aquarium (Table 1). Then, all aquaria were covered well with a cloth to prevent fish from escaping, and pores were made in each cloth to pass the aerator pipe and feed for fish. The X. hellerii fries were fed on diets in accordance with the treatments and replications (Table 1). The fish were fed twice a day with respective feed to apparent satiation, with the daily ratio being divided into two equal parts and fed during 10.00 a.m
and 17.00 p.m. At the beginning of the experiment, the feed was supplied at the rate of 10% of the body weight of X. hellerii, and gradually it was re-adjusted to 8%, 5%, 4%, and 3% every twenty days.

**Table 2. Proximate composition (dry matter basis) of different experimental feed used**

<table>
<thead>
<tr>
<th>Proximate composition (%)</th>
<th>Diet 1 (Formulated feed) T1</th>
<th>Diet 2 (Mega feed) T2</th>
<th>Diet 3 (Fast red feed) T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>5.34</td>
<td>4.85</td>
<td>0.95</td>
</tr>
<tr>
<td>Ash</td>
<td>14.46</td>
<td>13.52</td>
<td>11.38</td>
</tr>
<tr>
<td>Crude Protein</td>
<td>37.62</td>
<td>27.62</td>
<td>29.54</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>11.92</td>
<td>6.51</td>
<td>6.21</td>
</tr>
<tr>
<td>Lipid</td>
<td>10.61</td>
<td>3.23</td>
<td>5.21</td>
</tr>
<tr>
<td>Nitrogen free Extract (NFE)</td>
<td>20.10</td>
<td>44.27</td>
<td>46.72</td>
</tr>
</tbody>
</table>

3. **Sampling, water quality parameters**

The hydrobiological parameters, such as temperature, pH, dissolved oxygen (DO), ammonia and nitrite were weekly monitored throughout the experimental period between 9.00 am to 11.00 am of the day. The pH and temperature were measured by an electric digital waterproof pH meter (HANNA-211) and a mercury Celsius thermometer (1 div: 0.1°C), respectively. Other parameters such as DO, nitrate, ammonia etc. were measured by using a hack kit (HI3826).

4. **Measurement of growth parameters**

For the measurement growth parameter, red swordtail, X. hellerii were collected at each twenty (20) days interval from each aquarium. The total time spent out of the water was less than 5 seconds. To calculate and monitor various growth parameters of X. hellerii, individual weight was measured by using an electronic balance (readability 0.01 g) model KERN 572-33, Germany, and total length (cm) was measured by using a measuring board to the nearest 0.1cm, and then samples were returned to the respective aquarium. The following equations were used for the calculation of growth parameters:

- Mean weight gain (g) = Mean final weight – Mean initial weight
- Mean length gain (cm) = Mean final length – Mean initial length
- Percent weight gain (%) = \[\frac{\text{Mean final weight} - \text{Mean initial weight}}{\text{Mean initial weight}} \times 100\]
- Percent length gain (%) = \[\frac{\text{Mean final length} - \text{Mean initial length}}{\text{Mean initial length}} \times 100\]
- Average daily weight gain (g/day) = \[\frac{\text{Mean final weight} - \text{Mean initial weight}}{T}\]
Specific growth rate (SGR %/day) = \( \frac{\ln W_t - \ln W_i}{T} \times 100 \)

Food conversion ratio (FCR) = \( \frac{\text{Total feed fed (g)}}{\text{Total wet weight gain (g)}} \)

Food conversion efficiency (FCE) = \( \frac{\text{Live weight gain}}{\text{Amount of feed}} \)

Protein efficiency ratio (PER) = \( \frac{\text{Live weight gain(g)}}{\text{Crude protein fed (g)}} \)

Survival rate (%) = \( \frac{\text{Present number of fishes}}{\text{Total number of fishes}} \times 100 \)

5. Determination of proximate composition

The major nutritional composition of experimental feeds and experimental fishes were analyzed in the Fish and Animal Nutrition Laboratory, SAU. The Association of Official Analytical Chemists (AOAC, 2000) methods with slight modifications were used for the determination of proximate composition in fish feeds and swordtail fishes. The following equations were used:

\[
\text{Moisture} \text{ (%) } = \frac{\text{Original sample weight(g) } - \text{ Dried sample weight (g)}}{\text{Original sample weight (g)}} \times 100
\]

\[
\text{Ash(%) } = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100
\]

\[
\% \text{ Nitrogen } = \frac{\text{ml of titrant x strength of HCL (0.2N) } \times \text{ mili. Equivalent of N}_2}{\text{Weight of sample}} \times 100
\]

The protein percentage (wet or dry basis) was calculated as follows:

\[
\% \text{ Crude Protein } = \% \text{ N2 } \times 6.25 \text{ (animal source)}
\]

Or \[\% \text{ Crude Protein } = \% \text{ of N2 } \times 5.85 \text{ (Plant source)}\]

\[
\text{lipid(%) } = \frac{\text{Lipid weight } + \text{ Beaker weight } - \text{ Empty beaker weight}}{\text{Sample weight}} \times 100
\]

\[
\text{Crude fiber (%) } = \frac{\text{Wt of sample after air drying(g) } - \text{ Wt of sample after ashing(g)}}{\text{Weight of sample (g)}} \times 100
\]

\[
\text{Nitrogen Free Extract (NFE %) } = \{100 - (\text{moisture} + \text{crude protein} + \text{lipid} + \text{ash} + \text{crude fiber})\}.
\]

6. Data Analysis

One-way ANOVA (analysis of variance) with SPSS (Statistical package for social science, version, 20) were implied to perceive whether the parameters among the treatments were statistically significant or not. The mean values were compared by
Duncan’s multiple range test ([Duncan, 1955](#)) to test the significance of the difference between the treatments.

**RESULTS**

1. **Water quality parameters**

   The water quality parameters, viz. temperature, DO, pH, alkalinity, nitrite (NO$_2$), phosphate (PO$_4$), and ammonium (NH$_3$) did not significantly vary ($P>0.05$) among the treatments and were in the ranges considered as suitable limits for fish culture (Table 3).

   **Table 3.** Water quality parameters in three treatments during the experimental period

<table>
<thead>
<tr>
<th>Parameter</th>
<th>T$_1$</th>
<th>T$_2$</th>
<th>T$_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water temperature (°C)</td>
<td>27.33± 0.42</td>
<td>27.17 ± 0.29</td>
<td>26.97 ± 0.15</td>
</tr>
<tr>
<td>Dissolved oxygen (DO)</td>
<td>6.33±0.580</td>
<td>6.67±0.580</td>
<td>6.83±0.760</td>
</tr>
<tr>
<td>Alkalinity (mg/l)</td>
<td>6.76±0.25</td>
<td>6.60±0.340</td>
<td>6.57±0.150</td>
</tr>
<tr>
<td>pH</td>
<td>6.77 ± 0.14</td>
<td>7.11 ± 0.310</td>
<td>6.54 ±0.270</td>
</tr>
<tr>
<td>Nitrite (NO$_2$) (mg/l)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Phosphate (PO$_4$) (mg/l)</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Ammonium (NH$_3$) (mg/l)</td>
<td>0.34 ± 0.090</td>
<td>0.258 ± 0.00</td>
<td>0.319 ± 0.080</td>
</tr>
</tbody>
</table>

   $^1$Values are means of data obtained ± Std. Deviation (mean ± SD) of weekly determinations. The absence of superscripts indicates no significant difference among different treatments ($P>0.05$).

2. **Growth performance of red swordtail, X. helleri**

   The X. helleri samples were cultured with the feeding of three feed explicitly formulated feed in treatment T$_1$, mega feed T$_2$, and fast red feed in T$_3$. The growth performance of X. helleri was determined by calculating final weight (g), final length (cm), weight gain (g), length gain (cm), percent weight gain (%), specific growth rate (SGR), food conversion ratio (FCR), food efficiency ratio (FCE), protein efficiency ratio (PER) and survival rate (%). Significantly ($P<0.05$) higher final weight, percent weight gain and average daily weight gain were found in T$_3$, followed by T$_2$, and was lower in fish fed with diet T$_1$ (Table 4). The SGR (% day$^{-1}$) ranged from 3.72 to 3.27, and higher values were found in T$_3$, followed by T$_2$ and lower in T$_1$. There were significant ($P<0.01$) variations in SGR between T$_1$ and T$_2$, T$_1$ and T$_3$, but no significant difference was observed between T$_2$ and T$_3$ (Table 4). Significantly ($P<0.05$) higher FCR value was found in T$_1$, followed by T$_2$ and T$_3$ (Fig. 1a). Significantly ($P<0.05$) improved FCE and PER values were observed in three treatments (T$_1$>T$_2$>T$_3$) of cultured X. hellerii (Fig. 1b, c). The observed survival rate of X. helleri follows the order of T$_1$>T$_2$ > T$_3$, and significant ($P<0.05$) variations in values were detected between T$_1$ and T$_2$, T$_1$ and T$_3$ (Fig. 1d).
Table 4. Effect of different feed on the growth parameters of red swordtail, *X. helleri*

<table>
<thead>
<tr>
<th>Growth parameter</th>
<th>Treatment</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T&lt;sub&gt;1&lt;/sub&gt;</td>
<td>T&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Initial weight (g)</td>
<td>0.05±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.05±0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Final weight (g)</td>
<td>1.32±0.130&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.76±0.130&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Initial length (cm)</td>
<td>1.68±0.160&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.68±0.160&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Final length (cm)</td>
<td>5.06±0.410&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.39±0.160&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Net weight gain (g)</td>
<td>1.27±0.139&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.71±0.137&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Length gain (cm)</td>
<td>3.38±0.416&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.71±0.167&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Percent weight gain (%)</td>
<td>2540±2770&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3420±2750&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Percent length gain (%)</td>
<td>221.03±0.097&lt;sup&gt;a&lt;/sup&gt;</td>
<td>221.03±0.099&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Average daily weight gain (g/day)</td>
<td>0.013±0.002&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.017±0.001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>SGR (%)</td>
<td>3.27±0.110&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.56±0.080&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup>Values are means of data obtained ± Std. Deviation (mean ± SD) of 20 days’ interval determinations. Values in a row having the same superscript do not differ significantly (*p*<0.05) whereas values bearing the dissimilar letter (s) differ significantly (as per DMRT) * (*p*<0.05) and ** (*p*<0.01) significant at 5% and 1% level of probability, Ns=not significant.

**Fig. 1.** Effect of feed on the growth performance of red swordtail, *X. helleri* (values were expressed as mean ± std (n = 10), where bars with different superscripts represent the statistically significant (*P* < 0.05) difference.
3. Proximate composition analysis of red swordtail, *X. helleri*

The higher moisture content was noted in T2 (68.46±1.09%), followed by T3 (68.16±1.64%) and T1 (65.96±3.12%); nonetheless, values were not significantly (P>0.05) varied among the treatments (Fig. 2a). The higher ash content was observed in T1 (4.69±0.48%), followed by T2 (4.201±0.33%) and T3 (3.85±0.58%) and did not show any significant variation (P>0.05) among treatments (Fig. 2b). Significantly higher (P<0.05) crude protein content was found in T1, (15.078±0.55%) compared to T3 (13.427±0.224%) and T2 (13.127±0.49%) (Fig. 2c). However, T1 was significantly different (P<0.01) from T2 and T3, whereas no significant difference was found (P>0.05) between T2 and T3. Significantly higher (P<0.05) crude fiber content was recorded in T3 (3.047±0.18%) than T2 (2.423±0.12%) and T1 (2.262±0.11%) (Fig. 2d). The significantly (P<0.05) higher lipid content was noted in T1 (4.24±0.08%), followed by T2 (2.59±0.08%) and T3 (3.34±0.18%) treatments (Fig. 2e). The values for NFE content did not significantly vary (P>0.05) among T1, T2, and T3 (Fig. 2f).

**Fig. 2.** Effect of formulated T1, mega T2 and fast red T3 feed on the proximate composition of red swordtail, *X. helleri* (values were expressed mean ±std. error and bars with the same superscript represent non-significant and different superscripts showing the statistically significant (P<0.05) variation different).

**DISCUSSION**

The demand for artificial breeding and the culture of ornamental fishes increased due to its high economic value (Hoseinifar et al., 2015). Red swordtail *X. helleri* is one of the most important ornamental commercial fish species (Mousavi-Sabet & Ghasemnejhad,
1031 Feeding effect on growth and body composition of aquarium fish red swordtail

2013; Petrescu-Mag et al., 2013). Nutritional manipulation in fish feed is considered one of the most important goals in the ornamental fish culture plan (Firouzbakhsh et al., 2011). The present experiment aimed to assess the adaptive habituation and determine the effect of different feeds (formulated, fast red, and mega feed) on the growth performance and proximate profiling of red swordtail, X. helleri.

1. Water quality parameters

All water quality parameters of this experiment (temperature, DO, pH, alkalinity, nitrite, phosphate, and ammonium content) have not significantly varied among the three treatments and were in a suitable range for fish culture. The water quality parameters of the present study coincides with the result of Oliveira et al. (2008). They observed that Cardinal tetra an Amazonian ornamental fish can tolerate the temperature of 25-29ºC, pH (5.2-8.4), and unionized ammonia (0.022 mg/l). Kader et al. (2017) and Hossain et al. (2021) recorded similar ranges of water quality parameters in ponds of Mymensingh, and Noakhali, respectively.

2. Growth performance of red swordtail, X. helleri

The final weight (g) of X. helleri in the present study ranged from 1.32-2.05, with the order T₃ < T₂ < T₁ which concurs with the ranges (1.12-2.66) reported by Mohanta and Subramanian (2011). The final length (cm) of fishes in various treatments ranged from 4.65-5.84cm in 100 days, which was to some extent similar to the results of Tamaru et al. (2001) who recorded the length of X. helleri ranging from 3.14 to 6.16cm in 90 days. The average daily weight gain of X. helleri in the present study ranged from 0.0107-0.021 g/day. While, aligned ranges of weight gain (0.021-0.027 g/day) were noted by Dharmaraj and Dhevendaran (2010) after 50 days of feeding. Comparatively, much lower weight gain (0.002-0.008 g/day) was noted by Arulvasu et al. (2013) who assessed the effect of natural sourced carotenoid pigments on growth, survival and colouration of swordtail X. helleri. A significantly increased SGR (% day⁻¹) was found in T₃ (3.72), followed by T₂ (3.56%) and T₁ (3.27); fast red feed T₃ with 29.54% protein contents gives better SGR. The SGR value in sailfin molly (Poecilia latipinna) ranged from 3.62 - 3.86 %day⁻¹ (Vasagam et al., 2007) that are comparable to the present study. Anjur (2017) noted that, swordtail, X. helleri fry, fed with artemia showed better SGR value over bloodworm and earthworm.

Mean FCR in different treatments of the present study ranged from 1.19-1.72, followed by the order T₁ < T₂ < T₃. Lower FCR value indicates better feed quality thus X. helleri needs to consume less amount of feed to attain growth. Mohanta and Subramanian (2011) noted that, the FCR of X. helleri fish ranged from 1.48 to 2.15. While, FCE values (0.97±0.070) were noted in X. helleri fed on a diet without probiotics (Dharmaraj & Dhevendaran, 2010), which are somewhat similar to the present study. However, Dharmaraj and Dhevendaran (2010) observed comparatively higher ranges
of FCE of 1.42-2.27 in X. helleri fish fed on probiotics treated feed than in the FCE of the present study (0.67-1.002). Comparatively better PER (1.52-2.10) in swordtail was also observed by Mohanta and Subramanian (2011) than the PER of the present study (0.054-0.125). Mohanta and Subramanian (2011) observed higher PER ranges (1.52-2.10) in swordtail, which was higher than the present study. The survival rate (%) of swordtail fish ranged from 60- 89.67, with a higher order of T3 (86.67±3), followed by T1 (80±5) and T2 (65±5). Better survival rates (%) were observed in groups X. helleri fishes fed with artemia (100), followed by bloodworm (90), and earthworm (60) reported by Anjur (2017) who assessed the effect of diverse natural diets on the growth and survival of swordtail. The results of Radhika et al. (2007) reported higher survival in X. helleri juveniles fed Chironomus larvae compared to other formulated feed. Tamaru et al. (2001) reported a survival rate of swordtail (90.1%), which is close to the present study.

3. Body composition analysis of red swordtail, X. helleri

The proximate compositions of fish are protein, moisture, fat, mineral, and carbohydrates and variations in the proximate composition of fish which are closely related to the feed intake (Boran & Karaçam, 2011). The present study estimated X. helleri whole body composition explicitly moisture, protein, lipid, fiber, ash, and nitrogen-free extract substances. The highest moisture content was found in T2 (68.46±1.09%), followed by T3 (68.16±1.64%) and T1 (65.96±3.12 %). The moisture content of swordtail fish varied with feed type and ingredients (Radhika et al., 2007). Moreover, it is evident that the moisture content of ornamental fishes differs with feed treatment (Saghaei et al., 2015). The protein content was estimated as 15.078±0.55%, 13.427±0.224% and 13.127±0.49% in T1, T3, and T2, respectively. The variation in protein content of X. helleri muscle is mainly due to the use of different feeds in different treatments. The previous study found protein content in swordtail fish with ranges from 15.40% to 16.50% in different treatments after 50 days of feeding trial (Dharmaraj and Dhevendaran, 2010). A significantly higher lipid content (%) was observed in the fishes of T1 (4.24) <T3 (3.34) <T2 (2.59). The formulated feed contains a relatively higher level of crude lipid, and fishes in T1 also contain higher lipid content that may be linked with this. Increases in dietary lipid from 8% to 16% with the same protein level improved the growth performance of swordtail fry (Ling et al., 2006). Dharmaraj and Dhevendaran (2010) used various fiber contents (3.70-4.055%) in swordtail feed and noted (1.95-2.97%) fiber contents in fish bodies. The non-significantly increased ash content of X. hellerii was recorded in T1 (4.69±0.48%), T2 (4.201±0.33), and T3 (3.85±0.58%). The previous study also found ash content that differs from the dietary feed intake of swordtail fish (Shu-Chien et al., 2004; Radhika et al., 2007). The NFE content ranged from 7.775- 9.21 in three treatment groups of X. hellerii. The present study confirms the previous study of Dharmaraj and Dhevendaran (2010) who found
0.31% to 1.00% NFE content in swordtail fish muscles. This study observed higher body composition of *X. hellerii* in the fishes of T\(_1\) because they were fed with a formulated diet which contains 37.62% of CP and 10.61% of lipid. The present study agrees with that of Mohanta and Subramanian (2011) who found that, 40% of CP and 10 % of lipid increased the body composition of swordtail fish.

In the present study, the growth performance of *X. helleri* was lower in the T\(_1\) group, but the deposition rate of nutrients was higher in T\(_1\) fish tissue. This is due to the high percentage of nutrient content in diet I than in the other two diets. Formulated feed (Diet 1) contained mustard oil cake, which may be responsible for lower growth. Since mustard oil cake contains some anti-nutritional compounds, such as glucosinolates and their breakdown products, phenolics and phytates, which hinder the bioavailability of amino acids and minerals and depress fish growth (Naczk *et al*., 1992; Dijkstra *et al*., 2003; Latif *et al*., 2008). Fish can utilize a certain level of dietary lipid which depresses growth due to less feed consumption (Ellis & Reigh, 1991). In the present study, the dietary fiber content in T\(_1\) was 11.92%, which exceeds the tolerance limit (8%) and may be responsible for the declining growth in T\(_1\) fish. In this diet, rice bran percent may be reduced to decrease the fiber level (NRC, 1993; Fontainhas-Fernandes *et al*., 1999). Moreover, Diet 1 containing mustard oil cake may have some negative effects on growth performance due to the presence of erucic acid (Sehwag & Das, 2015). From the above results, it can be concluded that formulated feed can be a good choice by considering the cost and availability of feed, but it needs to reduce the lipid and protein content and ensure pre-treatment of feed ingredients (soaking and autoclaving) to prevent the antinutritional component.

**CONCLUSION**

Based on the overall growth performance and whole-body proximate carcass composition reflected that the red swordtail *X. helleri* has quite well habituated to all the experimental diets (formulated and commercial feed) used in this research. Although higher growth performance and nutrient utilization were noted in T\(_3\) (fast red feed), followed by T\(_2\) (mega feed) and T\(_1\) (formulated feed). However, the better proximate composition of whole- body carcass was noted in *X. hellerii* fed on formulated feed (T\(_1\)), followed by fast red feed (T\(_3\)) and mega feed (T\(_2\)) call further meaning full investigations on suitable and cost-effective feed formulation for this ornamental fish. This study also submits the necessity of executing further research on the physiological stress response, analysis of blood parameters, and biochemical aspects of *X. hellerii*. In the end, it could be anticipated that the results of the present study may contribute some initial benchmark insight to pave the way for further research on feeding trial experiments of *X. hellerii* in the context of tropical and subtropical areas of the world including Bangladesh.
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