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Effects of tank colour on growth and survival of taimen *Hucho taimen* (Pallas, 1773) larvae

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Abstract This study was conducted to evaluate the effect of tank colour on growth and survival of taimen *Hucho taimen* larvae. Larvae (initial weight 0.11 ± 0.01 g, 21 days after hatching) were cultured in the water flow-through system. Fifteen aquaria (200 L per aquarium) were randomly allocated into triplicate groups of 500 larvae. The outsides of the tanks were covered in red, blue, yellow, white, or black sheeting. Larvae were fed eight times a day by hand to apparent satiation. The experiment was conducted for 56 days. The results showed that the specific growth rate was significantly affected by tank colour, which was higher in the yellow tank than that of the tank (black or red) ($P < 0.05$). The tank colour did not significantly affect survival, condition factor, and feed conversion ratio among all the treatments ($P > 0.05$). The highest feed intake was observed in fish reared in the yellow tank, followed by that of the white, blue, or black tank, and the lowest was in fish in the red tank. In conclusion, the light-coloured tank (yellow or white) was optimum for rearing taimen larvae based on the growth performance.

Keywords *Hucho taimen* · Larviculture · Tank colour · Growth · Survival

Abbreviations

IBW	Initial body weight
FBW	Final body weigh
WG	Weight gain
SGR	Specific growth rate
FCR	Feed conversion ratio
CF	Condition factor
FL	Fork length

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Introduction

Most teleosts are visual feeders during their early life stages (Marchesan et al. 2005). The ability of these fish to detect and ingest their food can be affected by a number of factors including background colour. Different coloured tanks induce a variety of responses in relation to growth, survival, skin colour, stress response, neural and hormonal processes, behaviour and feed acceptance, or their combined effects in fishes (Papoutsoglou et al. 2000; Tamazouzt et al. 2000; Rotllant et al. 2003; Papoutsoglou 2005; Jentoft et al. 2006; Strand et al. 2007; Luchiari and Pirhonen 2008; Pawar et al. 2011; Kang and Kim 2013; Raghavan et al. 2013; Eslamloo et al. 2015; Karakatsouli et al. 2015; Okada et al. 2015; Ustundag and Rad 2015; Zhang et al. 2015; Li et al. 2016; Sierra-Flores et al. 2016). For instance, Eurasian perch, *Perca fluviatilis*, grew best in light-grey tanks (Tamazouzt et al. 2000); juvenile guppies, *Poecilia reticulata*, had a higher specific growth rate in blue tank (Ruchin 2004); and juvenile rainbow trout, *Oncorhynchus mykiss*, reared in green environments had higher specific growth rates than those reared in blue, white or red tanks (Luchiari and Pirhonen 2008). Barramundi, *Lates calcarifer*, from red aquaria were larger than the fish from green and blue aquaria (Pawar et al. 2011).

Improper tank colour would reduce the feed contrast (Monk et al. 2008) and growth (Downing and Litvak 2000) and increase aggression (Höglund et al. 2002) and stress (Papoutsoglou et al. 2000; Barton 2002; Barcellos et al. 2006; Martinez-Cardenas and Purser 2007; McLean et al. 2008; Cobcroft and Battaglene 2009; Alderman et al. 2012; Rahnama et al. 2015). In contrast, growth, feed efficiency and survival of some species, such as sand bass, *Paralabrax maculatofasciatus*, were not significantly affected by tank colours (Peña et al. 2005). These studies confirm that reactions to tank colour may vary with fish species (Papoutsoglou 2005).

Taimen, *Hucho taimen* (Pallas, 1773), is one of the most important and highly preferred coldwater fish in China. The high dress-out weight, less intramuscular bones, delicious flavour, nutritional value, recuperative and medicinal properties, and a ready market acceptance has made taimen highly popular in China. However, the production of taimen seed through artificial propagation is still limited and does not meet the increasing demands. In addition, taimen larvae suffer from high mortalities during their early stages, due to dietary deficiencies, problems in culture systems, transportation, and environmental deterioration. Thus, the determination of optimal culture conditions for cultured taimen larvae is essential for the maximization of taimen production and profitability.

Previous studies indicated that taimen larvae exhibit unusual behaviours such as the ability to feed under dark conditions and prefer weak-light or dark conditions in natural settings (Xu et al. 2008). However, no information is available on the effect of background colour on the performance of farmed taimen. The information on this work can be used to improve feeding regimes in the taimen hatcheries.

Materials and methods

Experimental design and rearing conditions

Hucho taimen larvae originated from controlled spawning wild brood stock and larviculture in the Bohai Coldwater Fish Hatchery, Chinese Academy of Fishery Sciences. Larvae were cultured in the water flow-through system. Fifteen aquaria (200 L per aquarium) were randomly allocated into triplicate groups of 500 larvae each. The outsides of the tanks were covered by red, blue, yellow, white, or black sheeting. To measure the background colour of the tanks, a portable spectrophotometer (WR-10, Weifu Inc., Shenzhen, China) was employed. The instrument had a D65 (1500 lx) daylight simulator lamp, and UV light was excluded during the measurements. Based on the CIELAB colour space analysis, the red tank showed an L* of 51.55, a* of 76.05, and b* of 62.38. The blue tank had an L* of 73.66, a* of 21.32, and b* of 12.73. The yellow tank showed an L* of 94.56, a* of −6.16, and b* of 26.32. The white tank showed an L* of 96.55, a* of 3.02, and b* of 1.08. The black tank showed an L* of 23.56, a* of 1.03, and b* of 1.56. Larvae (initial weight 0.11 ± 0.01 g, 21 days after hatching) were fed eight times a day by hand to apparent satiation. The experiment was conducted for 56 days. All the tanks were provided with the same spring water filtered through zeolum, corallite, and activated carbon. Water quality parameters were monitored daily. During the experimental period, all test tanks had the same water quality parameters: temperature = 14.82 ± 0.95 °C, pH = 7.39 ± 0.06, ammoniacal nitrogen = 0.012 ± 0.002 mg L^{-1}, and dissolved oxygen (YSI 6600 V2-2, Ohio State, USA) = 9.19 ± 0.05 mg L^{-1}. Approximately, 1.5 L s^{-1} water flow rate was supplied to the fish tanks. Light source above all tanks has optical flux $\varphi = 298.57$ lm, chromaticity coordinates $x = 0.3057$ $y = 0.3269/u' = 0.1937$ $v' = 0.4662$, colour value $Tc = 6918$ K, emission wavelength $\lambda d = 488.7$ nm, peak wavelength $\lambda p = 545$ nm, half-width $\Delta\lambda p = 10.5$ nm, and colour rendering index (CRI) $Ra = 84.0$. The photoperiod was set at 14 h light: 10 h dark and provided by fluorescence tubes (40 W). A timer was used to turn lights on and off. Illumination reached appropriately (300 lx) at the water surface. During the experimental period, larvae from each replicate were weighed every eight days weighing. The daily ration was adjusted every eighth day after weighing the fish from each replicate. The uneaten feed was syphoned out 2 h after each feeding, and oven-dried at 65 °C for 24 h to calculate the feed intake and conversion ratio. The faecal samples voided by the fish were collected daily from each tank by pipetting. The number of dead individuals was recorded to calculate the survival each tank. At the end of this experiment, the fish were starved for 24 h and then measured. The 50 larvae from each replicate were measured for the weight (precision 0.01 g) and fork length (precision 0.01 cm) to calculate the condition factor (CF). The total weight each tank was measured to calculate weight gain (WG), specific growth rate (SGR), and feed conversion ratio (FCR).

Diet preparation

The feed was formulated from commonly available ingredients (Table 1). Dry ingredients were sieved through a 60-mesh screen and homogenized by blending thoroughly in a feed mixer. The needed amount of fish oil and lecithin was added to the ingredients with the proper amount of water to prepare a dough that allowed pelleting (diameter 1.5 mm). Pellets were air-dried until they reached approximately 12 % moisture, and then stored at −20 °C until fed to the fish.

Data analysis

Growth performance was calculated as:

WG (%) = 100 × (final weight−initial weight)/initial weight.
SGR (% day^{-1}) = 100 × (ln average final weight−ln average initial weight)/days.
Survival (%) = 100 × (final number of fish/initial number of fish).

Table 1 Nutrients and ingredients used to prepare the basal diets (air-dry basis, %)

Ingredients	Composition
White fish meal	50.0
Isolated soy protein	6.0
Milk powder	10.0
Blood meal	10.0
Soybean lecithin	2.5
Fish oil	6.0
Dextrin	13.0
L-alanyl-L-glutamine	1.0
Premix*	1.5
Nutritional level	
Gross energy (MJ kg^{-1})	18.93
Moisture	12.12
Crude protein	50.41
Crude lipid	14.95
Ash	7.82

* Premix 1.50 % includes the following: choline 0.2 %; antimildew 0.05 %; magnesia 0.2 %; betain 0.10 %; antioxidant 0.025 %; vitamin premix 0.3 %; mineral premix 0.2 %; and zeolite 0.425 %. Vitamin and mineral mixture provide the following (kg^{-1} of the diet): V_C 100 mg; V_E 60 mg; V_{K3} 5 mg; V_A 15000 IU; V_{D3} 3000 IU; V_{B1} 15 mg; V_{B2} 30 mg; V_{B6} 15 mg; V_{B12} 0.5 mg; nicotinic acid 175 mg; folic acid 5 mg; inositol 300 mg; biotin 2.5 mg; pantothenic acid 50 mg; Fe 25 mg; Cu 3 mg; Mn 15 mg; Zn 30 mg; and I 0.6 mg

$$\text{FCR} = 100 \times (\text{dry diet intake})/(\text{weight gain});$$
$$\text{CF} = 100 \times (\text{body weight}/\text{fork length}^3).$$

Three replicates per treatment were used for statistical analysis. All data are expressed as mean ± standard deviation (SD). Application of SPSS software (version 13.0; SPSS Inc., Chicago, IL, USA), Shapiro–Wilk normality test on experimental data, matched the normal distribution and met the homogeneity of variance using analysis of variance. Subsequently, all data were subjected to one-way analysis of variance (ANOVA) followed by a comparison of means (Tukey's HSD test). A significance level of 95 % was considered to indicate statistical differences ($P < 0.05$). The figures were prepared using by SigmaPlot (version 12.5; Systat Software Inc., San Jose California, USA).

Results

This study showed that the growth of taimen larvae was affected by tank colour (Table 2). SGR was significantly affected by tank colour, which was higher in the yellow tank than that of the tank (black or red) ($P < 0.05$) (Fig. 1). There were no significant differences in SGR between the two tanks yellow and white ($P > 0.05$).

The tank colour did not significantly affect survival among all the treatments ($P > 0.05$). There was also no significant difference in condition factor among all the groups (red, black, blue, white, or yellow tanks) ($P > 0.05$). However, the lowest condition factor or survival in the red tank was observed.

Table 2 Growth performance of *Hucho taimen* larvae at the end of the 56-day growing trial

Indices	Tank colours					P value
	Black	White	Red	Blue	Yellow	
IBW (g)	0.11 ± 0.01	0.11 ± 0.01	0.11 ± 0.01	0.11 ± 0.01	0.11 ± 0.01	1.000
FBW (g)	0.60 ± 0.02^{ab}	0.69 ± 0.06^{cd}	0.57 ± 0.04^{a}	0.66 ± 0.07^{bc}	0.77 ± 0.04^{d}	0.003
FL (cm)	4.16 ± 0.03^{a}	4.37 ± 0.18^{ab}	4.11 ± 0.08^{a}	4.28 ± 0.12^{ab}	4.52 ± 0.07^{b}	0.006
WG (%)	432.25 ± 39.50^{a}	510.98 ± 41.15^{ab}	403.44 ± 45.86^{a}	478.91 ± 39.36^{ab}	587.33 ± 59.10^{b}	0.005
Survival (%)	89.93 ± 1.17	90.20 ± 2.62	89.67 ± 0.76	89.80 ± 2.91	89.67 ± 3.93	0.999
CF	0.84 ± 0.01	0.83 ± 0.03	0.82 ± 0.01	0.84 ± 0.02	0.85 ± 0.01	0.496
FCR	1.81 ± 0.05	1.79 ± 0.05	1.82 ± 0.03	1.81 ± 0.02	1.77 ± 0.03	0.628

Values represent mean ± standard deviation of pooled data from triplicates per treatment ($n = 3$). Means in the same row with different subscripts are significantly different ($P < 0.05$)

IBW initial body weight, *FBW* final body weight, *FL* fork length, *WG* weight gain, *CF* condition factor, and *FCR* feed conversion ratio

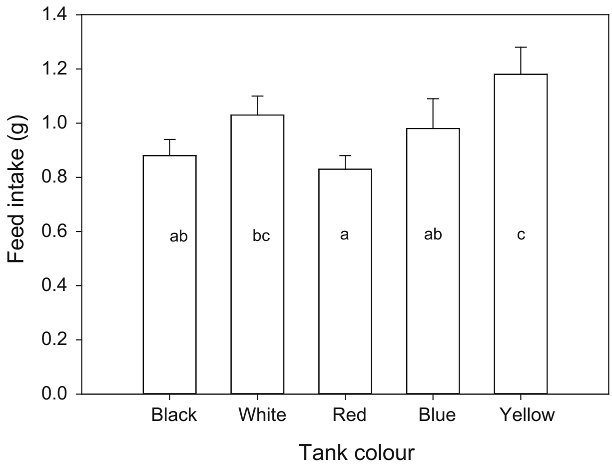

Fig. 1 Comparison of individual feed intake with different *tank colours*. Approximately, 95 % confidence intervals for difference in effects are provided. The *lower-case* letters indicate significant value ($P < 0.05$)

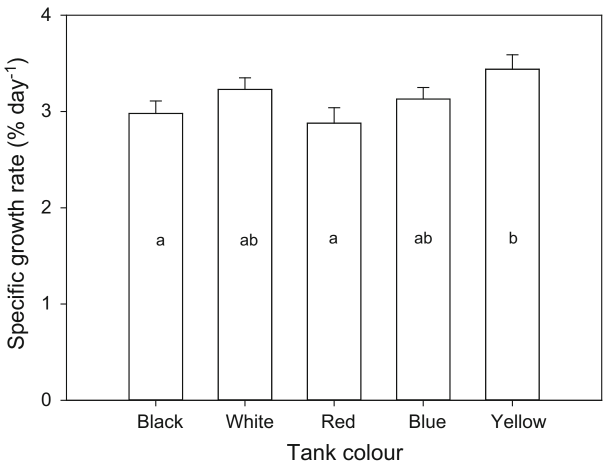

Fig. 2 Comparison of SGR with different *tank colours*. Approximately, 95 % confidence intervals for difference in effects are provided. The *lower-case* letters indicate significant value ($P < 0.05$)

The highest feed intake was observed in fish reared in the yellow tank, followed by that of the white, blue, or black tank and the lowest was in fish in the red tank (Fig. 2). There were no large differences in FCR among the groups ($P > 0.05$). The highest FCR was observed in fish reared in the red tank, followed by that of the black, blue, or white tank, and the lowest was in fish in the yellow tank.

Discussion

In the present study, light-coloured tanks (yellow, white and blue) provided better growth and feed intake of taimen larvae. There was little upwelling light in the tanks at low light intensity in this study. This may have resulted in impaired recognition of feeding by larvae in dark-coloured tanks (red and black), due to poor light dispersion and poor contrast between feed and background. Some larvae may be unable to detect and capture sufficient feed to sustain a growth rate compared to that observed in the light-coloured tanks (yellow, white, and blue). Inability to detect and capture sufficient feed may also have resulted in the higher mortalities observed in red or black tanks in this study. Similar reports have been demonstrated by a number of authors (Downing and Litvak 2000; Papoutsoglou et al. 2000; Tamazouzt et al. 2000; Woods 2000; El Sayed and El Ghobashy 2011; Raghavan et al. 2013). Rainbow trout were found to prefer white or light-coloured tanks to dark tanks, and the feed intake was higher for fish in dark tanks (Papoutsoglou et al. 2005). Eurasian perch which was found to differ in terms of their appetite, with fish in white and grey tanks having a greater feed intake than fish held in black tanks (Strand et al. 2007). Similar to sea bream, *Diplodus puntazzo* (Karakatsouli et al. 2015), there were no differences in feed conversion ratio among treatments. However, light-coloured tanks (yellow and white) provided lower feed conversion ratio in the present study, which was relatively consistent with weight gain. Thus, differences in growth are probably related to feed intake or feed efficiency.

Fish larvae reared in light-backgrounds may also have been less stressed than those reared in dark backgrounds, as has been reported in a number of fish species (Papoutsoglou et al. 2000; El Sayed and El Ghobashy 2011; Kang and Kim 2013; Okada et al. 2015). One of the most important mechanisms affecting the survival and growth of fish by rearing tank colour is the regulation of hormones—especially those relating to stress (Papoutsoglou et al. 2000). These researchers found that dark background-adapted fish exhibited higher cortisol level and lower performance compared with fish adapted to white backgrounds. Similar to goldfish, *Carassius auratus* (Eslamloo et al. 2015) and rainbow trout (Rahnama et al. 2015), the lower growth and feed intake of taimen larvae in the red and black groups also may be related to stress responses. In the previous study, elevated levels of cortisol were continuously observed in the young taimen reared in light-red tanks throughout the experiment (Wang et al. 2016), and stress responses energy-demanding processes that may increase the catabolic processes of cultured fish, and may reduce their growth rates (Strand et al. 2007; El Sayed and El Ghobashy 2011) and survival (Okada et al. 2015).

In contrast, some studies indicated that the dark-coloured tank is more preferable, presumably because dark-coloured tank walls could provide good contrast between feed and background (Downing and Litvak 1999). The larvae aggregated to the walls in light-coloured tanks, leading to stress, poor feeding, and body damage in striped bass, *Morone saxatilis* (Martin Robichaud and Peterson 1998) and Pacific bluefin tuna, *Thunnus orientalis* (Okada et al. 2015). Thus, many researchers suggest the use of dark-coloured tanks for larval rearing, because many larval fish are positively phototactic, which causes them to orient towards reflective surfaces (Karlsen and Mangor Jensen 2001). Moreover, the larvae tend not to accumulate along the walls (Naas et al. 1996), resulting in less damage due to abrasion.

On the other hand, other reports indicated that tank colour did not significantly affect larval growth and survival. For instance, larval growth performance of haddock (Downing and Litvak 1999) and spotted sand bass *Paralabrax maculatofasciatus* (Peña et al. 2005) reared in dark or light colours was similar. In Atlantic salmon, *Salmo salar*, there were no significant differences in growth when fish were maintained in either green- or grey-coloured tanks (Stefansson and Hansen 1989). Growth of Atlantic cod, *Gadus morhua*, was not impaired in white tanks compared to dark tanks (Monk et al. 2008). No significant differences were observed in the larval growth and survival of common carp, *Cyprinus carpio*, reared in white, black or green tanks (Papoutsoglou et al. 2000). It is clear from this discrepancy that the effect of background colour on fish performance is species specific (El Sayed and El Ghobashy 2011).

In the present study, taimen larvae seemed to prefer a yellow environment, similar to rainbow trout (Ustundag and Rad 2015) and Nile tilapia, *Oreochromis niloticus* (Luchiari et al. 2007), while red was better for zebrafish, *Danio rerio* (Spence and Smith 2008); blue for barramundi (Ullmann et al. 2011); white for goldfish (Eslamloo et al. 2015); dark blue and black for yellow catfish, *Pelteobagrus fulvidraco* (Raghavan et al. 2013); green for grouper, *Epinephelus coioides* (Zhang et al. 2015) and Atlantic cod (Sierra-Flores et al. 2016); and white and blue for turbot, *Scophthalmus maximus* (Li et al. 2016). Similar to barramundi (Ullmann et al. 2011), in red, black, and blue tanks, taimen larvae remained in relatively tight shoal; once fed, one or two individuals would commence feeding and then the whole shoal went to the water surface to feed. In yellow and white tanks, taimen larvae spread out throughout the tank and a few individuals prompted when fed and not all fish would begin feeding.

In addition, a clear difference in body colour was observed for taimen larvae, almost black fish rearing in the dark tanks (red and black) and pale rearing in the light-coloured tanks (blue, white, and yellow), which is similar to the findings of other studies (Marchesan et al. 2005; Strand et al. 2007). This indicated that the capacity of taimen larvae to change the body colour in accordance with tanks might reduce the problem of conspicuousness and reduce a potential source of stress (Strand et al. 2007).

Conclusions

This study revealed that the taimen larvae growth performance was significantly improved by rearing the fish in light-coloured tanks. Based on the specific experimental conditions, consideration has to be made that feed to background contrast within the tank. Our previous study indicated that there were no differences in growth performances in tanks of different colours for young taimen (6.8–6.9 g) and dark-coloured tanks led to stress responses (Wang et al. 2016); therefore, different-size classes of cultured taimen might be differently responded to different coloured tanks. Taimen larvae (2.0–3.0 g) exhibited a lower survival during the process of larviculture, and individuals with a growth advantage in the early stage (0.1–1.0 g) had the advantage of strong resistance when entered the next developmental stage (2.0–3.0 g). Unfortunately, this study did not extend a longer period and investigate the immune response, which were restricted by the specific experimental condition. Therefore, further studies could also investigate the chronic effects of background colours on taimen growth, stress, and immune reactions to confirm this study.

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