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Effects of the interaction between tank color and type of feed pellets on biological and physiological indicators in red hybrid tilapia (*Oreochromis mossambicus* × *Oreochromis niloticus*) juveniles reared in brackish water

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Abstract

The present work aimed to investigate the impacts of tank color (transparent, light blue, and red), feed pellet types (floating and sinking), and their interaction on the performance and welfare of red hybrid tilapia juveniles with an initial average weight of 19.59 g for a 50 day trial period following a 3 × 2 factorial design. Fish were cultured randomly at a stoking rate of 10 juveniles/100-L tank. Fish were fed 6 days per week at a rate of 4% biomass twice daily. Three replicates were performed for each measurement.

A two-way analysis of variance showed that using tanks of different colors (transparent, light blue, and red) has no impact on the growth, feed efficacy, survival rate, and blood composition (except for red blood cells, hematocrit, and triglycerides) of tilapia. Also, pellet types (floating and sinking) showed no significant alterations for the above variables except for glucose and hematocrit levels. Interestingly, the interaction between tank color and pellet type exhibited significant impacts on growth parameters, feed utilization, blood variables, and intestinal enzymes of red hybrid tilapia. Moreover, fish reared in transparent or light blue tanks and fed with floating diets performed the best for all evaluated parameters. Additionally, sinking pellets had better effects when combined with red (dark)-colored tanks.

KEYWORDS

floating feed pellets, growth parameters, red tilapia, sinking feed pellets, tank color

1 | INTRODUCTION

Aquaculture accounts for 80.53% of Egypt's total fish production, making it the country's primary source of seafood (General Authority for Fish Resources Development [GAFRD], 2019). It is, however, subject to many limitations, the most significant of which is the high cost of feed ingredients. Depending on the species and level of intensification, feeding costs make up between 40% and 60% of the variable production costs (M. F. A. Abdel-Aziz, Hassan, et al., 2021; Limbu & Jumanne, 2014). Therefore, researchers are attempting to identify ways to decrease the cost of feeding by employing less expensive feed alternatives or improving fish feeding efficiency.

There are three major ways to maximize feed utilization: (1) using feed additives, that is, herbs extracts (El-Dakar et al., 2008; Hussein et al., 2023), probiotics (M. Abdel-Aziz et al., 2020; El-Dakar et al., 2007; Shadrack et al., 2023), exogenous enzymes, and minerals in nanoparticles (Dawood et al., 2019, 2020), (2) establishing feeding strategies (M. F. Abdel-Aziz et al., 2016; M. Abdel-Aziz et al., 2020; M. F. Abdel-Aziz, Abdel-Tawwab, et al., 2021; El-Dakar et al., 2021), and (3) providing the optimal environmental conditions for the well-being of fish to maximize the utilization of each feed molecule added to the water (Abu-Elala et al., 2023; El Basuini, Teiba, et al., 2022; El Basuini, Zaki, et al., 2022; Teiba et al., 2020).

A sufficient understanding of the biological characteristics of fish is necessary for efficient fish rearing. Maintaining fish in an artificial environment different from their natural habitat may affect the fish's physiology and behavior. According to Brannas et al. (2001), the tank's color is one of the key environmental elements that can influence how well-cultured fish perform. Fish growth, size fluctuations, physiological state, body composition, and digestive enzymes are all negatively impacted by an inappropriate tank color (Downing & Litvak, 2000; Marchesan et al., 2005). Additionally, Mane et al. (2018) demonstrated that the tank color has a significant impact on the welfare of the cultured species and is connected with light intensity and spectrum.

Employing floating pellets versus sinking pellets is a topic of debate. Floating pellets are recommended for feeding in many studies because of their superior water stability, improved floating qualities, and higher energy content as compared to other pellets (Abdelhamid & El-Sh Ramadan, 2019; Yaqoob et al., 2010). Opponents, however, argue that floating feeds are more expensive. Furthermore, feeding some species with floating or sinking feed does not significantly affect their development rate (Limbu, 2015).

Therefore, the present study aimed to determine the suitable conditions for rearing red hybrid tilapia juveniles while ensuring their welfare and assessing the impact of the feed pellet type under these conditions. This is presumably the first study to estimate the impact of the interaction between the background color (transparent, light blue, and red) of the rearing tank and the type of feed pellets (floating or sinking) on the growth, body composition, blood parameters, and digestive enzymes of red tilapia juveniles reared in brackish water.

2 | MATERIALS AND METHODS

2.1 | Ethics statement

All experimental procedures, management rearing, handling, and sampling were approved by the National Institute of Oceanography and Fisheries Committee (Egypt) for ethical care and use of animals/aquatic animals (NIOF-IACUC, Code: NIOF-FI5-F-23-R-008).

2.2 | Site of experiment

The present study was conducted in a fish-feeding laboratory at the Faculty of Aquaculture and Marine Fisheries, Arish University. Experimental fish were obtained from the fish research center, Arish University, North Sinai, Egypt.

2.3 | Fish and experimental design

A 3 × 2 factorial design was used to examine the effects of three different tank colors (transparent, light blue, and red) and two feed pellet types (floating and sinking pellets). Fish were divided into six groups according to the rearing conditions: (1) TF group: transparent tank and floating pellets, (2) TS group: transparent tank and sinking pellets, (3) LBF group: light blue tank and floating pellets, (4) LBS group: light blue tank and sinking pellets, (5) RF group: red tank and floating pellets, and (6) RS group: red tank and sinking pellets. Each condition was reproduced three times.

A total of 120 red hybrid tilapia juveniles were transported to the experimental site in an oxygenated plastic tank. They were acclimatized to laboratory conditions for a week. After the adaptation period, the fish were randomly distributed into 12 plastic tanks (100 L) containing a water volume of 80 L. Tanks were supplemented with three air pumps (220 v, 50 Hz, 5 w). Fish were housed at a rate of 10 juveniles/tank. The initial weight of juveniles ranged between 18.8 and 20.50 g. The fish were reared in brackish water with 3-ppt salinity and fed twice daily, at 9 a.m. and 5 p.m., 6 days per week. The feeding was conducted by hand at a rate of 4% of the biomass. The water exchange rate was 40% of water volume daily. Fish were weighed every 2 weeks and counted fortnightly. The feeding rates were adjusted to body weight changes, and uneaten feed and fish waste were removed from the tank bottom using a small suction pump.

2.4 | Experimental diets

Two commercial diets consisting of floating or sinking pellets were obtained from Koudijs Kapo Feed Company, Borg El Arab, Egypt. They had a similar composition: 25% crude proteins, 4.33% crude fibers, and 5% crude lipids and gross energy (3800 kcal/kg diet).

2.5 | Water physicochemical analysis

Water temperature and pH were measured daily using a bench meter (HI2211, HANNA instruments, USA). The concentration of dissolved oxygen (DO, mg/L) was recorded weekly using an oxy-meter (HI98198, HANNA instruments, USA). The levels of total ammonia nitrogen (TAN, mg/L) were measured every 2 weeks using chemical methods (APHA, 1992).

2.6 | Calculation of growth indices

The following indices of growth were calculated:

$$\text{Weight gain}\,(\text{WG, g}) = \text{FBW} - \text{IBW},$$

where FBW is the final body weight (g) and IBW is the initial body weight (g).

$$\text{Average daily gain}\,(\text{ADG, g}) = \text{WG}/t,$$

where *t* is the experimental period (days).

$$\text{Specific growth rate}\,(\text{SGR}, \%) = (\ln \text{FW} - \ln \text{IW}/t) \times 100.$$

$$\text{Survival rate}\,(\text{SR}, \%) = (\text{number of fish at the end}/\text{number of fish at the beginning of the experimental period}) \times 100.$$

$$\text{Feed conversion ratio}\,(\text{FCR}) = \text{feed consumed in g per fish}/\text{WG in g}.$$

2.7 | Sample collection

At the end of the trial, all fish in each tank were weighed (after 12 h fasting), and the whole-body chemical composition was evaluated in three fish from each replicate. The proximate analyses of fish were conducted following the guidelines of the Association of Official Agricultural Chemists (AOAC, 2010). Three other fish from each replicate were anesthetized using MS-222 (tricaine methanesulfonate, 0.1 g L^{-1}, Sigma–Aldrich) to draw blood. Blood was obtained from the dorsal vein using 3-mL syringes and divided into two Eppendorf tubes: one containing heparin as an anticoagulant agent for hematological assessment (plasma was obtained by centrifugation at 3000 rpm for 10 min at 4°C) blood samples for biochemical analysis were collected in tubes free of anticoagulants. The collected serum samples were kept at −20°C until further analysis.

Red and white blood cell (RBC and WBC, respectively) counts were estimated following the method of Blaxhall and Daisley (1973). Hemoglobin concentration was measured using the cyanmethemoglobin method (Dorafshan et al., 2008). Serum glucose levels and glutamic oxaloacetic transaminase (GOT) and glutamic pyruvic transaminase (GPT) activities were analyzed photometrically using specific Spectrum Diagnostics kits (Egyptian Company for Biotechnology, Obour City, Egypt). Blood triglycerides were quantified using an RA-50 chemistry analyzer (Bayer) and readymade chemicals (kits) supplied by Spinreact Co., Spain.

The activity of alpha antitrypsin, amylase, and lipase in the intestinal tract of fish from which blood was drawn (six fish from each group) was detected using commercial assay kits (Nanjing Jiancheng CO., China).

2.8 | Statistical analysis

Data were analyzed using two-way analysis of variance. The differences among groups were determined using Tukey's test with $p \le 0.05$ as the significance level. All analyses were conducted using the SPSS Statistical Package Program v.20.

3 | RESULTS

3.1 | Water quality

The physicochemical parameters of water are shown in Table 1. There was no difference among the trial groups. The mean temperature, pH, DO and TAN levels ranged between 24.30–25.15°C, 7.51–8.13, 4.90–5.60 mg/L, and 0.285–0.321 mg/L, respectively.

3.2 | Growth indicators

Growth performance, feed efficacy, and survival rate are presented in Table 2. Regardless of the effect of the tank color, the FBW, WG, SGR, SR, and FCR were not significantly different ($p > 0.05$) between fish fed with floating pellets and those fed with sinking pellets. However, the FCR of fish fed with floating pellets was better than that of fish fed with sinking feeds.

The effects of the tank color, regardless of the pellet type, followed a similar trend as there was no significant difference ($p \le 0.05$) among color conditions. However, light tank color had a positive effect on the growth and FCR compared with the effects of a dark color, whereas the best WG, SGR, SR, and FCR were recorded for fish reared in light blue tanks. These values were intermediate for fish in transparent tanks. The lowest WG (12.13 g), SGR (0.242%/day), and SR (77.5%) and the highest FCR (2.71) were obtained for fish reared in red tanks.

Table 2 shows the effect of the interaction between tank color and pellet type. The FBW, WG, ADG, SGR, and FCR were significantly different ($p \le 0.05$) among groups, whereas the SR was not affected by the interaction between tank color and pellet type. Additionally, the FBW, WG, ADG, and SGR were not statistically different between the LBF and TF groups, and the growth performance indices of both groups were the highest. The growth

TABLE 1 Average water characteristics during the 50-day rearing period of red hybrid tilapia.

Groups	Temperature, °C	pH	DO, mg/L	Total ammonia nitrogen mg/L
TF	24.30 ± 0.20	8.08 ± 0.08	4.90 ± 0.30	0.285 ± 0.030
TS	24.28 ± 0.80	8.13 ± 0.99	5.45 ± 0.65	0.305 ± 0.025
LBF	24.42 ± 0.40	7.65 ± 0.51	4.90 ± 0.60	0.310 ± 0.035
LBS	24.65 ± 1.05	7.63 ± 0.03	5.60 ± 0.70	0.321 ± 0.038
RF	25.15 ± 0.95	7.50 ± 0.08	5.25 ± 0.65	0.291 ± 0.055
RS	24.06 ± 1.49	7.51 ± 0.01	5.55 ± 0.65	0.317 ± 0.081
p-Value	0.962	0.654	0.916	0.998
F-value	0.172	0.367	0.268	0.046

Abbreviations: DO, dissolved oxygen; TF, transparent tank and floating pellets; TS, transparent tank and sinking pellets; LBF, light blue tank and floating pellets; LBS, light blue tank and sinking pellets; RF, red tank and floating pellets; RS, red tank and sinking pellets.

TABLE 2 Growth performance, survival rate, and feed conversion ratio of red hybrid tilapia after a 50-day feeding scheme.

Parameters	IBW, g	FBW, g	WG, g	ADG, g/day	SGR %/day	SR%	FCR
Pellet type							
Floating	19.77 ± 0.40	34.90 ± 4.32	15.13 ± 4.32	0.302 ± 0.03	1.13 ± 0.11	78.33 ± 15.05	2.21 ± 0.37
Sinking	19.41 ± 0.47	32.49 ± 1.07	13.07 ± 0.81	0.261 ± 0.016	1.02 ± 0.04	83.33 ± 17.22	2.36 ± 0.180
p-Value	0.56	0.22	0.30	0.30	0.41	0.58	0.72
F-value	0.31	1.53	1.10	1.09	0.60	0.27	0.10
Tank color							
Transparent	18.89 ± 0.47	33.02 ± 1.95	14.13 ± 1.83	0.282 ± 0.036	1.10 ± 0.11	82.5 ± 8.77	2.18 ± 0.37
Light blue	19.42 ± 0.52	35.46 ± 1.76	16.04 ± 1.30	0.320 ± 0.026	1.20 ± 0.05	82.5 ± 5.95	1.96 ± 0.13
Red	20.47 ± 0.27	32.61 ± 1.54	12.13 ± 1.70	0.242 ± 0.034	0.921 ± 0.11	77.5 ± 10.3	2.71 ± 0.42
p-Value	0.08	0.490	0.281	0.280	0.180	0.88	0.30
F-value	3.89	0.760	1.428	1.430	2.077	0.10	1.30
Interaction between tank color and pellet type							
TF	18.99 ± 0.81	36.30 ± 0.70[a]	17.31 ± 0.11[a]	0.346 ± 0.002[a]	1.29 ± 0.045[a]	80.00 ± 15[a]	1.54 ± 0.11[c]
TS	18.80 ± 0.80	29.75 ± 0.95[b]	10.95 ± 0.15[b]	0.219 ± 0.003[b]	0.918 ± 0.021[b]	85.00 ± 15[a]	2.82 ± 0.03[ab]
LBF	19.89 ± 0.71	37.92 ± 2.09[a]	18.03 ± 1.37[a]	0.360 ± 0.027[a]	1.28 ± 0.035[a]	80.00 ± 10[a]	1.87 ± 0.22[bc]
LBS	18.95 ± 0.85	33.00 ± 1.5[ab]	14.05 ± 0.65[ab]	0.281 ± 0.013[ab]	1.11 ± 0.001[ab]	85.00 ± 10[a]	2.05 ± 0.18[abc]
RF	20.45 ± 0.45	30.50 ± 2.00[b]	10.05 ± 2.45[b]	0.201 ± 0.049[b]	0.795 ± 0.175[b]	75.00 ± 15[a]	3.23 ± 0.67[a]
RS	20.50 ± 0.50	34.72 ± 1.18[ab]	14.22 ± 1.68[ab]	0.284 ± 0.03[ab]	1.05 ± 0.117[ab]	80.00 ± 20[a]	2.20 ± 0.34[abc]
p-Value	0.392	0.044	0.028	0.028	0.038	0.397	0.08
F-value	1.230	4.659	5.61	5.591	4.892	1.227	3.469

Note: Values (mean ± SE) with different letters in the same column indicated significant differences ($p \leq 0.05$).

Abbreviations: ADG, average daily gain; FBW, final body weight; FCR, feed conversion ratio; IBW, initial body weight; LBF, light blue tank and floating pellets; LBS, light blue tank and sinking pellets; RF, red tank and floating pellets; RS, red tank and sinking pellets; SGR, specific growth rate; SR, survival rate; TF, transparent tank and floating pellets; TS, transparent tank and sinking pellets; WG, weight gain.

performances of the RS and LBS groups were intermediate, and the TS and RF groups had the lowest indicator values. The FCR significantly changed among groups, the best FCR was recorded for the TF (1.54) group and increased progressively in the LBF (1.87), LBS (2.02), RS (2.20), and TS (2.82) groups to reach its higher level (3.23) in the RF group.

3.3 | Whole-body biochemical composition

The fish body composition is presented in Table 3. The effects of the pellet type were not significant regardless of the tank color. However, fish fed with floating pellets had higher moisture and ash levels and lower fat and protein contents than those fish fed with sinking pellets. Additionally, Table 3 shows that there were significant differences in the fish body contents in response to the tank color regardless of the pellet type. The highest protein contents were recorded in fish reared in red and transparent tanks. In contrast, fish from the light blue tank exhibited the highest fat and ash contents and the lowest moisture levels. The interaction impacts between tank color and pellet type show significant alterations in the body composition. The lowest moisture percentage and highest fat percentage were recorded in the LBS group compared to other groups. Additionally, the ash content was significantly higher in the LBF group compared with other groups. Meanwhile, the highest values of protein contents were in TF, TS, RF, and RS groups compared with LBF and LBS groups.

TABLE 3 Composition (% dry weight) of red hybrid tilapia after a 50-day rearing period.

Parameters	Moisture%	Fat%	Ash%	Protein%
Pellet type				
Floating	72.18 ± 1.15	16.66 ± 0.31	18.65 ± 1.64	64.68 ± 1.79
Sinking	70.50 ± 4.21	17.85 ± 1.14	16.49 ± 1.035	65.66 ± 1.46
p-Value	0.709	0.337	0.287	0.676
F-value	0.148	0.980	1.229	0.179
Tank color				
Transparent	78.46 ± 2.44^{a}	15.74 ± 0.26^{b}	16.85 ± 1.26^{ab}	67.40 ± 1.33^{a}
Light blue	64.86 ± 3.32^{b}	19.10 ± 1.25^{a}	20.39 ± 1.87^{a}	60.50 ± 0.65^{b}
Red	70.71 ± 0.61^{b}	16.92 ± 0.54^{ab}	15.46 ± 1.07^{b}	67.61 ± 0.67^{a}
p-Value	0.01	0.045	0.096	0.001
F-value	8.02	4.457	3.078	18.45
Interaction between tank color and pellet type				
TF	74.77 ± 2.02^{b}	16.1 ± 0.40^{b}	16.12 ± 2.12^{b}	67.78 ± 2.52^{a}
TS	82.15 ± 2.15^{a}	15.39 ± 0.01^{b}	17.58 ± 2.02^{b}	67.03 ± 2.01^{a}
LBF	70.38 ± 2.22^{b}	17.15 ± 0.85^{b}	23.33 ± 1.67^{a}	$59.52b \pm 0.82^{b}$
LBS	59.34 ± 0.66^{c}	21.06 ± 1.06^{a}	17.46 ± 1.04^{b}	61.484 ± 0.02^{b}
RF	71.4 ± 0.60^{b}	16.75 ± 0.25^{b}	16.30 ± 0.50^{b}	66.75 ± 0.75^{a}
RS	70.03 ± 0.97^{b}	17.10 ± 1.30^{b}	14.43 ± 2.14^{b}	68.47 ± 0.83^{a}
p-Value	0.001	0.023	0.09	0.017
F-value	21.48	6.27	3.24	6.74

Note: Values (mean ± SE) with different letters in the same column indicated significant differences ($p \leq 0.05$).
Abbreviations: TF, transparent tank and floating pellets; TS, transparent tank and sinking pellets; LBF, light blue tank and floating pellets; LBS, light blue tank and sinking pellets; RF, red tank and floating pellets; RS, red tank and sinking pellets.

3.4 | Hematological and biochemical analysis

Blood parameters are shown in Table 4. Hematological and biochemical indicators were not significantly affected by the pellet type except for glucose and hematocrit levels, which were significantly lower in fish fed with floating pellets. The tank color significantly impacted RBC counts and triglycerides levels, which were significantly lower in fish housed in red tanks, whereas they were not different between fish reared in transparent and blue tanks.

The effects of the interaction between tank color and pellet type on the WBC count, hematocrit, GPT activity, and plasma glucose levels were not significant among the groups. In contrast, the RBC count, hemoglobin levels, GOT activity, and triglyceride levels were significantly changed. The TF, TS, RS, and LBF groups exhibited the highest RBC count. Additionally, the LBF groups had the highest hemoglobin levels, whereas these levels were intermediate in TF, TS, LBS, and RS groups and the lowest in the RF condition. GOT activity was the lowest in the TF group, intermediate in the LBF and RS groups, and the highest in the RF, TS, and LBS groups. The TF and LBF groups had the highest triglyceride levels, whereas the RS and LBS groups had intermediate amounts and RF and TS groups had the lowest levels.

3.5 | Intestinal enzymes activities

Figure 1 shows the activities of red hybrid tilapia intestinal enzymes after a 50-day rearing period. Alpha antitrypsin levels were significantly increased in the RF, TS, and LBS groups compared with those in the TF, LBF, and RS groups (Figure 1a). Lipase concentrations were significantly higher in the LBF, TF, LBS, and RS groups than in the RF and TS groups (Figure 1b). Amylase levels were not significantly different ($p < 0.05$) among the experimental groups (Figure 1c).

4 | DISCUSSION

The current investigation demonstrated that altering tank colors or feed pellet types had no impact on the water quality. All of the parameters, including temperature (Ngugi et al., 2007), pH (Makori et al., 2017), DO and TAN levels (Caldini et al., 2015), were also within the ideal ranges for tilapia culture. These results agree with those of Afia and David (2017) and Khan et al. (2022).

Regarding the growth performance and effects of the pellet type, there was no significant difference between fish fed with floating pellets and those fed with sinking pellets. However, floating pellets had a positive effect ($p < 0.05$) on the SR and FCR compared with that of the sinking pellets. These findings are corroborated by those from previous studies showing no significant difference in FCR and growth rate of tilapia fed with floating or sinking pellets (Kamruzzaman et al., 2021). Similarly, Ajani et al. (2011) and Limbu and Kyewalyanga (2015) found that the growth and feed consumption of *Clarias gariepinus* were similar between fish fed with floating or sinking pellets. Furthermore, Abdelhamid and El-Sh Ramadan (2019) and Kawser et al. (2016) showed that the SR did not differ with the pellet type.

However, many studies reported that fish growth performances are significantly affected by the pellet feed type. For example, Kawser et al. (2016) showed that floating and sinking pellets caused differences in tilapia fry growth. Similarly, floating feed pellets promote the growth of tilapia (Abdelhamid & El-Sh Ramadan, 2019; Abou-Zied, 2015; Kamruzzaman et al., 2021), Chinese major carps (Yaqoob et al., 2010), and olive flounder (Kim & Shin, 2006) compared to that of fish fed with sinking pellets. These different effects might be caused by floating pellets being more settled in the water than sinking pellets, which are partly lost because they leach into the water. Additionally, some feed is lost because it settles at the bottom of ponds and is mixed with bottom waste, preventing fish from eating it. Hence, the FCR value increases. The FCR value might also be higher because the fish activity and upward

TABLE 4 Blood parameters of red hybrid tilapia after a 50-day rearing period.

Parameters	Hb, g/dL	RBCs, 10^6/cm	WBCs, 10^3/cm	Hct, vol%	GPT, U/L	GOT, U/L	Glucose, ng/L	Triglycerides, mg/dL
Pellet type								
Floating	7.86 ± 0.31	2.39 ± 0.14	140 ± 1.70	23.85 ± 0.42	5.56 ± 0.12	11.96 ± 0.36	62.53 ± 1.17^b	105.17 ± 2.26
Sinking	7.33 ± 0.26	2.23 ± 0.05	142 ± 1.60	22.90 ± 0.25	5.93 ± 0.15	12.40 ± 0.24	66.33 ± 0.40^a	102.67 ± 0.84
p-Value	0.08	0.32	0.11	0.09	0.22	0.32	0.027	0.357
Tank color								
Transparent	8.00 ± 0.10	2.45 ± 0.06^a	139.50 ± 1.70	23.47 ± 0.36ab	5.45 ± 0.04	12.00 ± 0.35	64.25 ± 1.64	104.25 ± 1.96^a
Light blue	7.35 ± 0.20	2.47 ± 0.12^a	141.25 ± 1.58	24.17 ± 0.41a	5.65 ± 0.17	12.02 ± 0.41	62.95 ± 1.60	106.25 ± 1.86^a
Red	7.45 ± 0.30	2.03 ± 0.03^b	142.38 ± 2.67	22.62 ± 0.20b	6.15 ± 0.12	12.52 ± 0.39	67.00 ± 0.41	101.5 ± 2.32^b
p-Value	8.00 ± 0.10	2.45 ± 0.06^a	139.50 ± 1.70	23.47 ± 0.36ab	5.45 ± 0.04	12.00 ± 0.35	64.25 ± 1.64	104.25 ± 1.96^a
Interaction between tank color and pellet type								
TF	8.00 ± 0.20^a	2.55 ± 0.03^a	138.00 ± 2.08	24.00 ± 0.50^{ab}	5.40 ± 0.02^c	11.35 ± 0.15b	61.50 ± 0.30^b	107.50 ± 1.12^a
TS	8.00 ± 0.11^a	2.35 ± 0.08^b	141.00 ± 3.014	22.95 ± 0.05^{bc}	5.50 ± 0.05^c	12.65 ± 0.05^{ab}	67.00 ± 1.00^a	101.00 ± 1.50^b
LBF	7.65 ± 0.10^{ab}	2.65 ± 0.09^a	142.00 ± 2.073	24.85 ± 0.15^a	5.35 ± 0.05^c	11.50 ± 0.50^b	60.40 ± 0.90^b	109.00 ± 1.40^a
LBS	7.05 ± 0.22^b	2.25 ± 0.07^b	140.50 ± 3.15	23.50 ± 0.30^{bc}	5.95 ± 0.04^b	12.55 ± 0.50^{ab}	65.50 ± 0.20^a	103.5 ± 1.20^{ab}
RF	7.95 ± 0.05^a	1.97 ± 0.04^c	141.75 ± 5.01	23.00 ± 0.32^{bc}	5.95 ± 0.13^b	13.05 ± 0.08^a	66.00 ± 0.80^a	99.00 ± 4.30^b
RS	6.95 ± 0.03^b	2.09 ± 0.04^c	143.00 ± 3.9	22.25 ± 0.25^d	6.35 ± 0.08^a	12.00 ± 0.65^{ab}	68.00 ± 0.50^a	104.13 ± 2.20^{ab}
p-Value	0.035	0.001	0.916	0.040	0.00	0.047	0.021	0.042

Note: Values (mean ± SE) with different letters in the same column indicated significant differences ($p \leq 0.05$).
Abbreviations: GOT, glutamic oxaloacetic transaminase; GPT, glutamic pyruvic transaminase; Hb, hemoglobin; Hct, hematocrit; TF, transparent tank and floating pellets; TS, transparent tank and sinking pellets; LBF, light blue tank and floating pellets; LBS, light blue tank and sinking pellets; RBC, red blood cell; RF, red tank and floating pellets; RS, red tank and sinking pellets; WBC, white blood cell.

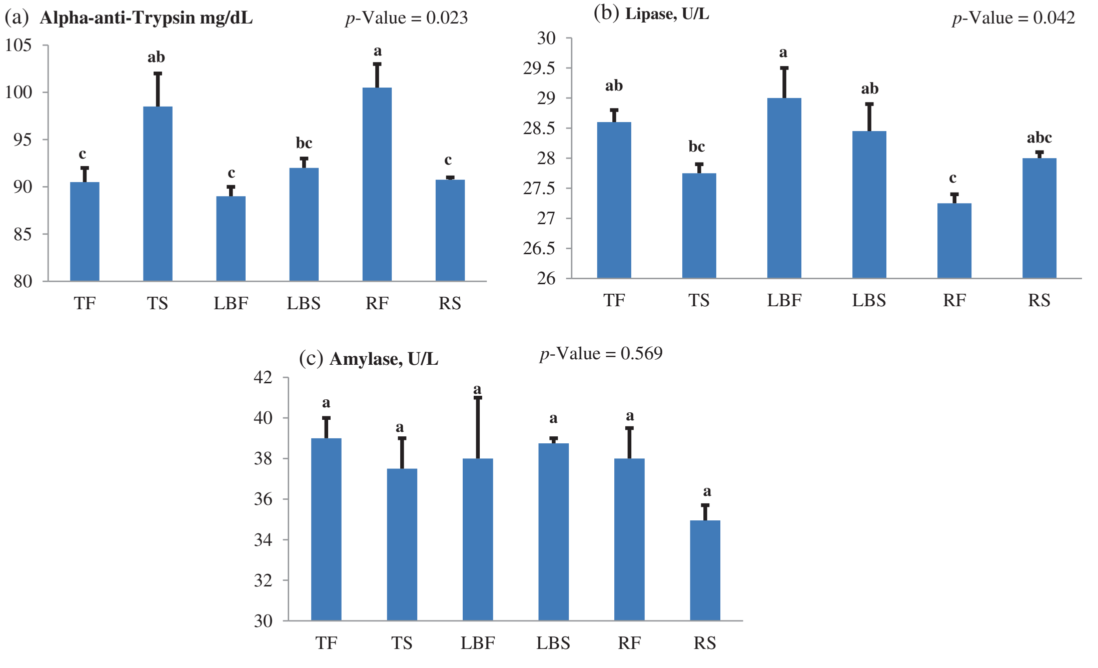

FIGURE 1 (a) Alpha-anti-trypsin, (b) Lipase, and (c) amylase of red hybrid tilapia fingerlings reared in tanks with different colors and different pellet types for 50 days. Values (mean ± SE) with different letters indicated significant differences ($p \leq 0.05$). LBF, light blue tank and floating pellets; LBS, light blue tank and sinking pellets; RF, red tank and floating pellets; RS, red tank and sinking pellets; TF, transparent tank and floating pellets; TS, transparent tank and sinking pellets.

movements performed to obtain the pellets from the surface of the water improve the performance of the fish's digestive system. Moreover, the processes of manufacturing floating pellets (extrusion) allow the starch to be highly digestible to provide feed containing more energy and being more palatable than sinking feed. Additionally, the extrusion processes destroy harmful microorganisms or toxic compounds in feed ingredients. These hypotheses regarding the greater FCR value obtained with floating feed are supported by other studies (Abdelhamid & El-Sh Ramadan, 2019; Yaqoob et al., 2010).

We also showed that the fish growth performances, survival, and FCR were not altered by different tank colors, regardless of the pellet type. Ghavidel et al. (2020) have also demonstrated that growth parameters and SR were not affected by the tank color. Moreover, Morshedi et al. (2022) reported that the FCR of Asian sea bass reared in white-, red-, blue-, and black-colored tanks for 6 weeks did not differ significantly. However, previous research by Santisathitkul et al. (2020), Üstündağ and Rad (2015), and El-Sayed and El-Ghobashy (2011) showed that enclosures of different colors significantly impacted the growth performance, and this effect was species-specific.

In summary, cultured tanks of different colors elicit a variety of responses in growth, mortality, skin color, behavior, and feed efficiency in many species. Additionally, several reports showed that the performances of fish housed in tanks of different colors significantly depend on the species and stages of their life (Ghavidel et al., 2020; Papoutsoglou et al., 2005), but it is conceivable that many factors, such as the type of pellets and light wavelength and intensity, abolish the effects of the tank color. Accordingly, the analysis of the effects of the interaction between tank color and pellet type showed that fish responded to a preferred tank color according to its suitability for seeing feed pellets, whether floating or sinking.

The interaction between tank colors and pellet types significantly affected the fish growth performances and FCR. Fish in light-colored tanks and fed with floating pellets (TF and LBF groups) had the best growth indicators.

However, the growth rates of fish housed in dark-colored tanks with sinking pellets (RS group) were better than those of fish kept in light-colored tanks with sinking pellets (LBS and TS groups) or dark-colored tanks with floating pellets (RF group). This inconsistency may be because the fish's ability to visualize the pellets is affected by the tank color and optical period as reported by Hubbs and Blaxter (1986). Furthermore, El-Sayed (2006) observed that the fish's visual recognition of feed pellets depends on several factors including the feed amount, pellet type and size, and tank color. Therefore, in addition to the aforementioned advantages of using the floating feed, the vision of the fish might improve because of the light reflecting on the surface of the water in light-colored tanks leading to an increased intake of floating feed pellets but not submersible pellets. This hypothesis is consistent with other studies showing that cleared, light-colored tanks have a positive effect on the growth performances of *Clarias magur* (Ferosekhan et al, 2020), *Liza ramada* (El-Sayed & El-Ghobashy, 2011), *Perca fluviatilis* (Strand et al., 2007), and *Cyprinus carpio* (Papoutsoglou et al., 2000). Similarly, Santisathitkul et al. (2020) recorded superior feed utilization parameters, that is, recorded a lower FCR value, and growth indices in Asian sea bass reared in transparent tanks. Yamanome et al. (2005) also found that using light-colored tanks increases somatic growth and decreases locomotor activity, consequently saving energy.

Our findings regarding the growth responses of fish reared in dark-colored tanks with floating pellets corroborate the ideas of Qin et al. (2004) who emphasized that fish take a longer time to find the pellets in dark-colored tanks. However, we also showed better growth performance of fish housed in red tanks with sinking pellets. This is partly followed by the Morshedi et al. (2022) study and possibly explained by a better contrast between red or dark-colored tanks and sinking pellets than that between dark-colored tanks and floating pellets.

Our statistical analysis revealed a significant impact of the pellet type on the fish's whole-body content in moisture, proteins, fat, and ash. These data are completely in agreement with previous work (Kawser et al., 2016) and close to the results obtained by Kamruzzaman et al. (2021) showing that the fat, ash, and moisture body contents were unchanged, whereas the protein levels were significantly higher in fish fed with floating pellets. The tank color also affected the fish's body composition. However, other studies (El-Sayed & El-Ghobashy, 2011; Ghavidel et al., 2020; Papoutsoglou et al., 2000) did not find significant variations in the body composition of fish housed in tanks of different colors.

The pellet type alone had no observable effect on hematological and blood biochemical indices, except for the plasma glucose levels that were significantly lower in fish receiving floating feed than in fish getting submerged feed. Although there were no statistically significant differences, the blood indices in fish fed with floating forage were better than those of fish fed with sinking feed. These observations were supported by Kamruzzaman et al. (2021) who showed by analyzing hematological indicators that the different pellet types did not significantly impact tilapia health. Moreover, Afia and David (2017) completely agree with our observations as they reported higher RBC count and hemoglobin levels in fish fed with floating pellets compared with those in fish receiving the sinking feed, whereas fish fed with sinking pellets had the highest WBC count. The higher glucose levels in fish fed with sinking pellets might be associated with increased stress response or might be a sign of decreased well-being compared with that of fish receiving the floating feed. Interestingly, decreased plasma glucose levels and GOT and GPT activities indicate that the fish's health and welfare need to be improved (Mohapatra et al., 2014).

As shown in Table 4, most hematological and plasma indicators were not significantly different among fish housed in tanks of different colors, regardless of the pellet type. Similarly, Eslamloo et al. (2015) and Morshedi et al. (2022) showed that hematological indicators were not affected by the tank color in goldfish or Asian sea bass. Additionally, Santisathitkul et al. (2020) did not observe significant effects of the tank background on hemoglobin levels, hematocrit, and GOT and GPT activities.

However, the blood indicators were better in fish reared in light-colored tanks, especially transparent tanks, than those of fish kept in red tanks. Additionally, RBC counts and plasma triglyceride levels were higher in fish housed in transparent and light blue-colored tanks than in fish kept in red tanks. These observations agreed with previous work (Ghavidel et al., 2020).

The interaction between the pellet type and tank color significantly impacted some blood parameters, and the best physiological status was achieved by fish reared in transparent and light blue tanks and fed with floating pellets. These fish had high levels of RBC, hemoglobin, hematocrit, and triglycerides and low levels of glucose, WBC, GOT, and GPT activities. Interestingly, increasing hemoglobin levels and hematocrit is a strategy employed to meet the greater demand for oxygen during growth by increasing the oxygen amount carried in blood (Montero et al., 1999). WBCs are the fish defense cells, and their count increases in fish exposed to stress factors such as anti-nutrition factors and microorganisms, which are more present in sinking diets (Ayoola, 2011). Additionally, triglyceride concentrations are used to evaluate endogenous lipid transport (Du et al., 2005).

The light intensity, tank color, and pellet type also affected the fish's digestive enzymes, thereby influencing feed efficiency. Ghavidel et al. (2020) also showed that the background color of the tank significantly impacts the activities of all digestive enzymes and measured the highest lipase concentration in fish housed in a blue tank. Conversely, Chan et al. (2008) demonstrated that the activity of fish digestive enzymes changes according to the nutritional and physiological status and thus did not consider the digestive enzyme activity as an indicator of fish growth.

5 | CONCLUSION

Using tanks of different colors (transparent, light blue, and red) has no impact on the growth, feed efficacy, survival rate, and blood composition (except for RBCs, hematocrit, and triglycerides) of tilapia. Also, pellet types (floating and sinking) showed no significant alterations for the above variables except for glucose and hematocrit levels. Interestingly, the interaction between tank color and pellet type exhibited significant impacts on growth parameters, feed utilization, blood variables, and intestinal enzymes of red hybrid tilapia. Impacts of feed type and/or tank color need further experimentation with different aquatic species, which may respond differently.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

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