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Tolerance Level of Domesticated Asian Red-Tail Catfish *Hemibagrus Nemurus* to Salinity, Acidity, and Temperature Variability

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Abstract: The Asian redtail catfish *Hemibagrus nemurus* is Indonesian native fish proposed for catfish culture diversification project. Prior to be commercialized and widely distributed, it is imperative to evaluate environmental tolerances of the catfish for successful breeding programs and its aquaculture development program. This research was carried out to evaluate the optimum tolerance range and physiological responses of domesticated *H. nemurus* exposed to different salinity, acidity, and temperature. Fish used in this experiment were the second generation of *H. nemurus* produced at the Research Institute for Freshwater Aquaculture and Fisheries Extension (RIFAFE), Bogor, West Java, Indonesia. A total of 12 fish for each treatment were exposed to different salinity (0 ppt (control), 5 ppt, 10 ppt, 12.5 ppt, 15 ppt and 17.5 ppt), pH (4, 5, 7 (control), 9 and 10), and temperatures (15℃, 20℃, 25℃, 28.5℃ (control), 32.5℃, 35℃, and 40℃) for 12 days observation until fish reached their Loss of Equilibrium (LOE). Cortisol, hemoglobin, and glucose were investigated to study the stress response happened. This research reveals that the domesticated Asian redtail catfish are able to be acclimated to slightly brackish-water environment (≤10 ppt), have more resilience in acidic than alkaline water (pH 5.0 to 7.35), and can adjust in wide range of temperatures (25℃ to 32.5℃). In salinity exposure, significant physiological effects existed between controls and treatments ($P<0.05$) except glucose. For pH, cortisol was the best indicator to see the effect of exposure ($P<0.05$). The last for temperature exposure, the only cortisol was enabled to be used as the indicator of stress response. From the study, it found that cortisol level analysis was the best indicator to detect stress responses of the catfish that would be important to mitigate unpredictable environmental events and early warnings in the changes of environmental quality in culture system. We would recommend that the domesticated *H. nemurus* can be developed for the new catfish aquaculture candidate as it met a requirement to tolerance evaluation on different water quality levels which its responses was commonly similar compared to other existing aquaculture species.

Keywords: loss of equilibrium, physiological effect, environmental tolerance, catfish, *Hemibagrus nemurus*.

馴化亞洲紅尾鯰半袋鼠對鹽度、酸度和溫度變化的耐受水平

摘要: 項目。在商業化和廣泛分發之前，必須評估鯰魚的環境耐受性，以實現成功的育種計劃及其水產養殖發展計劃。本研究旨在評估馴化 半袋鼠暴露於不同鹽度、酸度和溫度的最佳耐受範圍和生理反應。本實驗中使用的魚是印度尼西亞西爪哇茂物淡水水產養殖和漁業推廣研究所 生產的第二代 神经。每種處理共有 12 條魚暴露於不同的鹽度（0 點（對照）、5 點、10 點、12.5 點、15 點和 17.5 點）、酸鹼度（4、5、7（對照）、9 和 10 ）和溫度（15℃、20℃、25℃、28.5℃（對照）、32.5℃、35℃ 和 40℃）觀察 12 天，直到魚達到失去平衡。研究皮質醇、血紅蛋白和葡萄糖以研究發生的應激反應。這項研究表明，馴化的亞洲紅尾鯰能夠適應微鹹水環境（≤10 點），對酸性水（酸鹼度 5.0 至 7.35）的適應能力強於鹼性水（酸鹼度 5.0 至 7.35），並且可以在較寬的溫度範圍內調節。 25°C 至 32.5°C）。在鹽分暴

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露中，除葡萄糖外，對照組和處理組之間存在顯著的生理效應（P<0.05）。對於酸碱度，皮質醇是觀察暴露效果的最佳指標（磷<0.05）。最後一次用於溫度暴露，唯一的皮質醇被啟用作為壓力反應的指標。從研究中，它發現皮質醇水平分析是檢測鯰魚應激反應的最佳指標，這對於減輕不可預測的環境事件和早期預警養殖系統環境質量變化具有重要意義。我們建議可以為新的鯰魚水產養殖候選者開發馴化的 神经，因為它滿足對不同水質水平的耐受性評估的要求，與其他現有水產養殖物種相比，它的反應通常相似。

关键词： 失衡、生理效應、環境耐受性、鯰魚、半场 gs 睡眠 s。

1. Introduction

Water quality plays an important role in aquaculture system regarding health, survival, and fish production [1]. Typically, aquaculture activities need to consider physio-chemical parameters (e.g. temperature, dissolved oxygen, pH, salinity, ammonia, and nitrite) and it would be different relied on different species and life stages. Water quality variations occurred in aquaculture systems will strongly affect fish physiological functions relating to growth, metabolic rate, behavior, and survival [2]. Significant effects of water quality on farmed fish can be observed either at a high concentration or at a low concentration relied on each parameter. Therefore, understanding resilience of each fish species on different environmental stressors is beneficial for the successful rearing management of farmed species [3].

There are still many native Indonesian freshwater fish that have not been domesticated properly for aquaculture development [4-6]. Among members of the Hemibagrus genus, the Asian redtail Hemibagrus catfish is the most potential candidate for cultivation in Indonesia. Several studies related to domestication programs have been carried out, such as the early development of *H. nemurus* [7], the effect of domestication on morphometric characters [8], as well as growth and nutritional value [9]. At present, the second generation of domesticated *H. nemurus* has been produced at the research station. To be commercialized and widely accepted, it is imperative to test domesticated fish under various conditions for tolerance before being officially released.

Fish reared in aquaculture systems can often experience poor water quality conditions, which might impair their physiological responses [10]. Critical tolerance of fish in response to different environmental stressors can be assessed as fish experience their loss of equilibrium (LOE). LOE can be observed, as fish is unable to swim upright or respond to a physical stimulus [11]. Each fish species has different responses to environmental changes and this could alter fish morphology, behavior, and physiology [12]. Physiological responses of the fish can be detected from blood parameters such as glucose, hemoglobin, and cortisol as common stress biomarkers related to environmental changes [13]. Several previous studies had been conducted related to the effects of environmental stressors on catfish physiological responses such as effects of salinity on catfish, *Heteropneustes fossilis* [14], temperature on Asian catfish *Clarias batrachus* [15], and pH on striped catfish *Pangasianodon hypophthalmus* [16]. However, the effects of salinity, pH and temperature on the Asian redtail catfish has not been studied. Thus, this study aims to evaluate the tolerance and physiological responses of domesticated Asian redtail catfish subjected to different salinities, pH, and temperatures as environmental stressors.

2. Materials and Methods

2.1. Origin of Fingerlings

The second generation of domesticated fish fingerlings were obtained from the hatchery facilities at the Research Institute for Freshwater Aquaculture and Fisheries Extension (RIFAFE), Bogor, West Java, Indonesia. The fingerlings (total length: 11.78 ± 0.28 cm; weight: 14.39 ± 1.78 gr) were transported to the rearing tanks in the RIFAFE laboratory. Fish were acclimatized a week in the three rectangular tanks (60 x 60 x 60 cm) prior to treatments.

2.2. Experimental Design

To assess the resilience of fish on environmental stressors, 12 fish per treatment were acclimatized at different salinity, pH, and temperature treatments. In this study, the effects of salinity on the resilience of fish were conducted following the procedure from Mattioli, Takata [17] in determining maximum salinity tolerance as fish experienced loss of equilibrium. Different salinity regimes were prepared in aerated rectangular tanks (40 L, 40 x 30 x 30 cm) including 0 ppt (control), 5 ppt, 10 ppt, 12.5 ppt, 15 ppt, and 17.5 ppt. Salinity was measured by using a salinity refractometer (Trans Instruments RSA0100A, Singapore). In addition, we also measured the conductivity by using a conductivity meter (Lamotte Cond 6, USA). Investigation of fish resilience on different pH regimes was set in acidic to alkaline pH treatments. The acidic pH was prepared by adding Nitric Acid (HNO3) solution, while the alkaline pH was made by adding Sodium Hydroxide (NaOH) solution. Each solution was gradually added to water in aerated rectangular tanks (40 L, 40 x 30 x 30 cm) until the targeted pH value was reached. The pH levels tested for the resilience test were control (6.0-8.0), acid (4.0 and 5.0), and alkaline (9 and 10). During the observation, water pH was checked regularly with a digital pH meter (Lamotte pH 5 plus, USA). Experiments to evaluate the effect of different temperatures on fish were set in aerated rectangular tanks (40 L, 40 x 30 x 30 cm) equipped with an automatic thermostat (Resun CL450). The targeted temperatures prepared for this experiment were control (28.5℃), high (32.5℃, 35℃, and 40℃), and low temperature (15℃, 20℃, and 25℃).

Parameters observed in this study were the abnormality of behavior and critical tolerance at the fish loss of equilibrium (LOE critical). Investigation of the effects of different salinity, pH, and temperature on fish survival was carried out over 12 days. 12 fish for each treatment was measured in their total length and weight. To evaluate the physiological response of fish to different environmental stressors, blood samples were collected in the ventral venipuncture of the vertebral artery at the end of the study as the fish experienced LOE. Blood plasma was analyzed including glucose, hemoglobin, and cortisol. Prior to collecting blood samples, fish were anesthetized using an anesthetic solution (2-phenoxyethanol, dose: 0.5 ml/L water). Glucose levels were measured using a blood glucose reader (ACCU-CHEK Active, Roche, Germany). Hemoglobin levels were measured using the Sahli's method, while cortisol was analyzed using Cortisol ELISA kit (EIA-1887, DRG Instruments GmbH, Germany) and microplate photometer (Biosan HiPo MPP-96, Latvia) following the procedure from Prakoso *et al.* [7]. Abnormalities of the fish exposed to different environmental stressors were also observed, including abnormal swimming behavior, abnormal ventilatory function, and abnormal skin pigmentation. During the study, the measurement of dissolved oxygen value and temperature was conducted using a dissolved oxygen meter (Lutron DO-5510, Taiwan) and a digital pH meter (Lamotte pH 5 plus, USA).

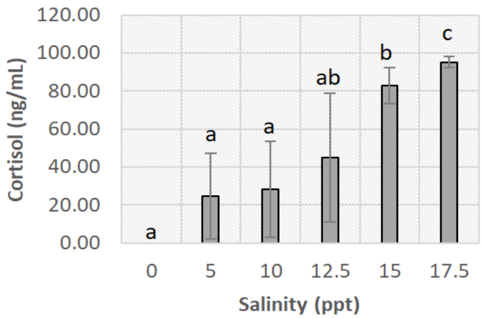
2.3. Statistical Analysis

The effects of salinity, pH, and temperature on physiological responses on fish were statistically evaluated using analysis of variance (ANOVA) to evaluate significant differences of cortisol, glucose, and hemoglobin in the experiment, followed by Least Significant Difference (LSD) to identify the different responses among treatments. The significance level was set to □= 0.05. Statistical analyses were performed R Statistic.

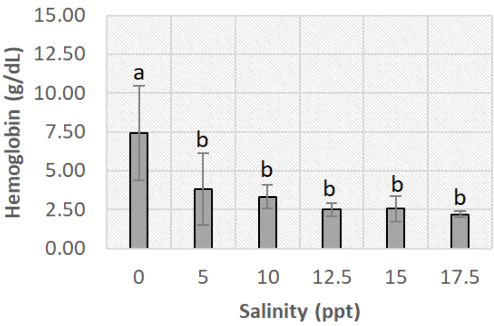
3. Results and Discussion

3.1. Tolerance of Catfish to Different Salinity Treatments

The Asian redtail catfish exposed to salinities over 12 days in the rearing tank shows different stress responses to higher salinity indicated by abnormality in behavior and morphological responses. Fish can survive over 12 days of exposure at salinity 0, 5, and 10 ppt (Table 1). At this salinity range, fish showed normal swim and active responses to the feed. The fish experienced abnormality in behavior and morphology correlate with increasing salinity and it may lead to mortality as the fish were kept at a salinity level over 10 ppt. At higher salinity, the clinical sign of abnormality of H. nemurus occurred at 12.5 and 15 ppt on day 10 indicated by LOE. Furthermore, at 17.5 ppt, the fish experienced LOE faster than other salinity levels in this study. Most fish reached LOE after being exposed to 17.5 ppt salinity for 6 hours. Prior to reaching LOE, the fish became hypoactive, gathered on the surface, loss of schooling, erratic vertical movement, and darkened color.



(a)



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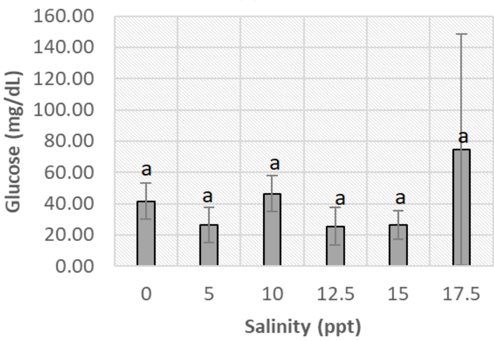

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Fig. 1 Stress responses of the Asian redtail catfish *H. Nemurus* were observed from cortisol (a), hemoglobin (b), and glucose (c) levels exposed to different salinity levels over 12 days. Letters indicate statistically significant differences between treatments (P < 0.05)

To determine the stress response of fish to different salinities, observation on blood parameters including glucose, hemoglobin, and cortisol are presented in Figure 1.

Table 1 Salinity tolerance of the Asian redtail catfish *H. nemurus* exposed to different salinities over 12 days in the tanks

Salinity treatment (ppt)	Conductivity (ms)	Fish number	Total Length (cm)	Total Weight (g)	12-days acclimated?	LOE
0 (control)	0.25 ± 0.013	12	11.93 ± 1.24	13.17 ± 2.58	Yes	-
5	9.85 ± 0.25	12	12.23 ± 0.83	13.99 ± 2.98	Yes	-
10	16.29 ± 0.78	12	11.91 ± 0.95	12.88 ± 2.72	Yes	-
12.5	20.34 ± 0.38	12	12.00 ± 1.07	13.62 ± 3.21	LOE	11 fish LOE at day 10
15	23.93 ± 0.26	12	11.58 ± 0.83	11.80 ± 2.18	LOE	11 fish LOE at day 10
17.5	27.97 ± 0.84	12	11.81 ± 1.16	12.39 ± 4.02	LOE	12 fish LOE at 6 hours

Note: LOE - loss of equilibrium

Table 2 Water quality parameter of salinity, pH and temperature tolerance test in experimental tanks

Parameters	Salinity treatments (ppt)					
	0 (control)	**5**	**10**	**12.5**	**15**	**17.5**
Temperature (℃)	27.92 ± 0.64	27.45 ± 0.69	27.31 ± 0.73	27.19 ± 0.63	27.26 ± 0.59	26.93 ± 0.23
DO (ppm)	7.05 ± 0.44	6.62 ± 0.81	6.69 ± 0.78	6.70 ± 0.90	6.66 ± 0.86	5.73 ± 0.67
pH	6.90 ± 1.00	7.37 ± 0.43	7.83 ± 0.38	7.72 ± 0.47	7.82 ± 0.37	7.80 ± 0.45
	pH treatments					
	7 (control)	**4**	**5**	**9**	**10**	
Temperature (℃)	28.53 ± 0.69	28.90 ± 0.94	28.60 ± 0.69	28.20 ± 0.66	28.30 ± 0.85	
DO (ppm)	6.75 ± 0.66	6.68 ± 0.43	6.88 ± 0.36	7.10 ± 0.28	6.65 ± 0.21	
	Temperature treatments (℃)					
	28.5 (control)	**20**	**25**	**32.5**	**35**	
Dissolved oxygen (ppm)	6.75 ± 0.66	7.80 ± 0.74	7.68 ± 1.02	6.68 ± 0.43	5.92 ± 0.29	
pH	7.35 ± 0.59	7.23 ± 0.21	7.19 ± 0.16	7.27 ± 0.38	7.31 ± 0.38	

The fish exposed to 0-10 ppt salinity can normally live for 12 days of the experiment. Increased water salinity levels were followed by increased plasma cortisol, which indicated that fish were distressed by increasing salinity exposure (Figure 1a). In contrast, hemoglobin levels decreased from low to high salinity (Figure 1b). Meanwhile, the fish exposed to 17.5 ppt salinity has the highest level of glucose (Figure 1c). There are no significant differences in cortisol levels at salinity 0, 5, 10 ppt, and 12.5 ($P > 0.05$), while a significant difference occurred as compared to salinity 15, and 17.5 ppt ($P<0.05$). Hemoglobin level of H. nemurus at 0 ppt salinity showed a significant difference compared to other treatments ($P < 0.05$). Moreover, in terms of glucose level, no significant differences were found among treatments ($P > 0.05$). Water quality during the study showed optimal values for the growth and survival of fish subjected to different salinity (Table 2). There are no significant differences in temperature, dissolved oxygen, and pH among different salinity treatments ($P>0.05$).

Salinity is one of the environmental stressors that limit the resilience of fish. Aquatic habitats with stable salinity levels are usually inhabited by stenohaline fish species, while waters with fluctuating salinity such as in rivers connecting estuaries are mostly inhabited by euryhaline fish species [18]. Results from the present study showed that the fingerlings of domesticated Asian redtail catfish can survive at salinity from 0 to 10 ppt. Similar results in other catfish species were found in striped catfish *Pangasianodon hypophthalmus* and African catfish *Clarias gariepinus* which can normally live and grow well with salinity ranging from 0 to 10 ppt over 13 days and 20 days experiment, respectively [19, 20]. In the present study, fish experienced LOE at 12.5 ppt indicating that Salinity Maximum Tolerance (SMT) for Asian redtail catfish would be 10 ppt. It shows similar performance compared to freshwater European perch *Perca fluviatilis* with similar SMT value at 10 ppt [21]. The SMT value on the second generation of H. nemurus is higher compared to the other catfish species such as *Heteropneustes fossilis* (6 ppt) [14] and *Lophiosilurus alexandri* (7.5 ppt) [17]. This indicates that the Asian redtail catfish can be categorized as having an excellent resilience on salinity as the other freshwater fish species (stenohaline) are commonly unable to survive at the salinity above 5 ppt [22]. Salinity alters fish blood biochemistry related to clinical status, energy use, and fish metabolism in response to extreme environmental changes [23]. Glucose levels generally increase with increasing salinity [14].

3.2. Tolerance of Fish to Different pH Treatments

The Asian redtail catfish can normally live at pH 5 and control (7.35 ± 0.59) (Table 3). The fish could survive for three days at pH 4, and then they experienced LOE on the fourth day of the experiment. Similarly, LOE of *H. nemurus* occurred at pH 9 and pH 10 on the third day of pH exposure. The effect of extreme pH treatments of both acidic and alkaline pH impaired the physiological response of the Asian redtail catfish. Fish cortisol levels at acidic pH (4) and alkaline pH (9 and 10) showed significant increases compared to pH 5 and control (Figure 2a). Cortisol levels at pH 4, 9, and 10 were significantly different from pH 5 and control (P<0.05). Hemoglobin level at pH 5 and control was higher compared to acidic and alkaline pH treatments (Figure 2b) but there is no significant difference among treatments (P>0.05). Meanwhile, significant differences in glucose levels were identified at pH 5 and pH 4 (P<0.05) (Figure 2c). During the experiment, water quality showed optimal values for the growth and survival of fish subjected to different pH levels (Table 2). No significant differences were found in temperature and DO (P>0.05).

Extreme pH occurred in aquatic habitats has a negative effect on the morphology and physiology of the fish. pH values below 4.5 and above 9 could have a detrimental impact on the fish survival as it degrades the cell membrane of the fish [24]. The African catfish *Clarias gariepinus* exposed to pH 4.3 and 9.2 resulted in 100% mortality after eight days [25]. In aquaculture, pH is an essential parameter affected by other water quality parameters, fish survival, and its effect varies among fish species. The effects of fluctuated pH in fish relate to survival, morphology, and fish behavior. Prior to LOE, the morphological and behavioral responses of *H. nemurus* to acidic and alkaline pH conditions were hypoactive, excessive mucus, skin erosion, and irregular swimming. A similar condition also occurred in tilapia exposed to acidic pH [26]. During this condition, cortisol tend to increase as fish were exposed to extreme waters with acute stress levels [27]. Moreover, glucose values generally increase as stress increases in fish [24]. This is in accordance with this study, which showed the highest glucose level observed at pH 4 and followed by pH 10. Maintaining the optimum pH level would be necessary for the farmers to regularly check pH levels in their fish farming activities. Water quality management is important to prevent fluctuated pH to avoid stress and maintain the survival of farmed fish [26]. Each fish species has the capability to adapt to the environment with fluctuated pH for a long period. However, the changes of pH value more than 1.5 above or below the recommended pH resulted in adverse impacts for farmed fish [24].

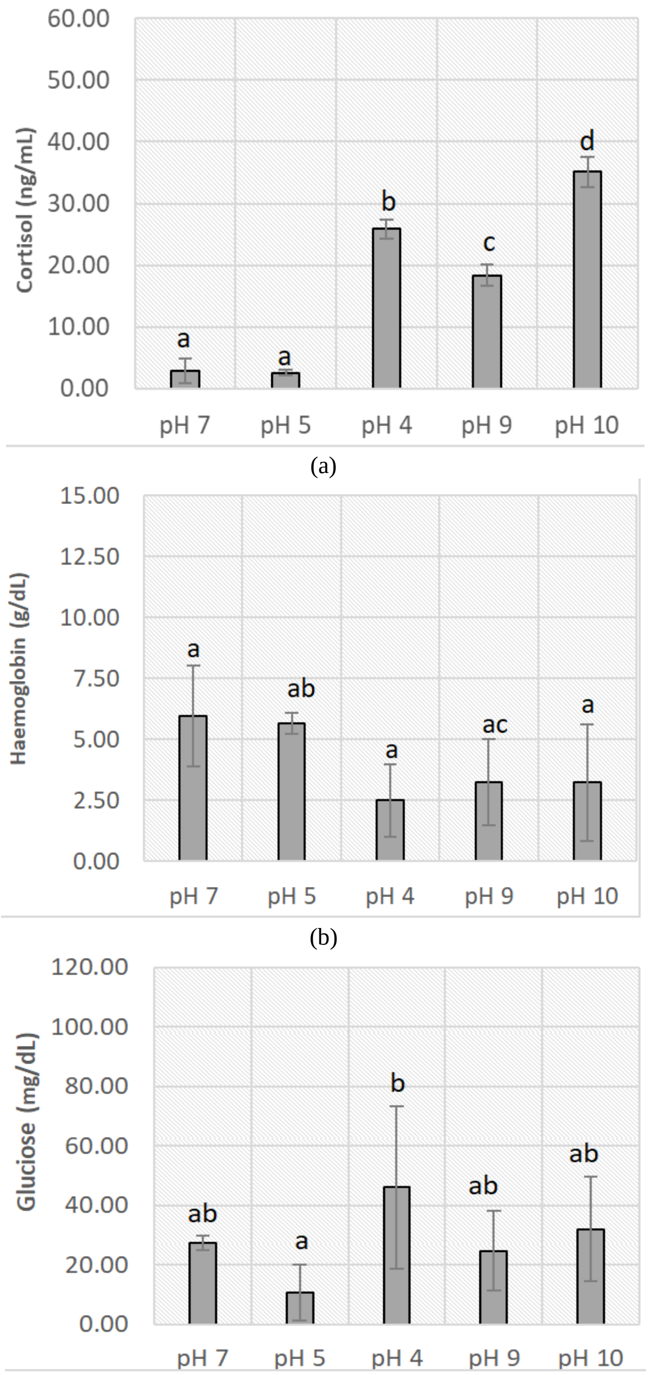

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Fig. 2 Stress responses of the Asian redtail catfish H. nemurus were observed from cortisol (a), hemoglobin (b), and glucose (c) levels exposed to different pH levels over 12 days. Letters indicate statistically significant differences between treatments (P < 0.05)

Table 3 pH tolerance of the Asian redtail catfish *H. nemurus* over 12 days in the rearing tanks

pH treatments	**pH range**	**Fish number**	**Total Length (cm)**	**Total Weight (g)**	**12-days acclimated?**	**LOE**
pH 4.0	4.00 ± 0.37	12	11.68 ± 0.88	15.67 ± 3.73	LOE	11 fish (day 4)
pH 5.0	5.20 ± 0.32	12	11.57 ± 0.67	14.14 ± 2.41	Yes	-
pH 7 (control)	7.35 ± 0.59	12	11.33 ± 1.05	13.00 ± 4.64	Yes	-
pH 9.0	9.25 ± 0.07	12	11.46 ± 1.32	13.53 ± 4.66	LOE	12 fish (day 3)
pH 10.0	10.05 ± 0.35	12	11.5 ± 0.95	13.85 ± 3.31	LOE	12 fish (day 3)

Note: LOE - loss of equilibrium

3.3. Tolerance of Fish to Different Temperature Treatments

The results showed that Asian redtail catfish live and move normally at the temperature range from 25 to 32.5℃ (Table 5). At 35℃, the fish started to show abnormal behavior such as hypoactive, gathered at the bottom of the tanks, hyperventilation, and breathing irregularly. On the fourth day of the treatments, the fish color became dark and they experienced LOE. A similar pattern occurred at 20℃ as the fish become hypoactive, under reactive to stimulus, abnormal vertical orientation, and finally LOE on the fourth day.

The water temperature was found to be lethal to fish at 40℃ where the fish immediately LOE after five minutes of exposure. A similar result was found at the coldest temperature treatment in this study (15℃). The fish immediately experienced irregular vertical movements and eventually LOE after five minutes of exposure. Based on cortisol level, *H. nemurus* showed a higher stress response at 20℃ and 35℃ as compared to 28.5℃ and 32.5℃ (Figure 3a). Cortisol levels at 25, and 28.5℃ did not differ significantly ($P > 0.05$), they were significantly different compared to 20, 32.5℃, and 35℃ ($P < 0.05$). Hemoglobin level at the control temperature (28.5℃) had a higher value, while it decreased in line with rising and lowering temperature (Figure 3b). However, hemoglobin levels in all treatments did not differ significantly ($P > 0.05$). On the other hand, blood glucose levels generally increase with increasing water temperature (Figure 3c). Glucose level differed significantly at 35℃ as compared to other temperature treatments ($P < 0.05$). Water quality during the study showed optimal values for the growth and survival of fish subjected to different temperatures (Table 2). No significant differences were found in pH and DO during the experiment ($P > 0.05$).

Water temperature can affect fish survival through various factors that affect the biochemical system and physiological process, and it can even be lethal as it is above a critical point that cannot be tolerated by fish [28]. In this study, *H. nemurus* can normally live at a temperature ranging from 25 to 32.5℃.

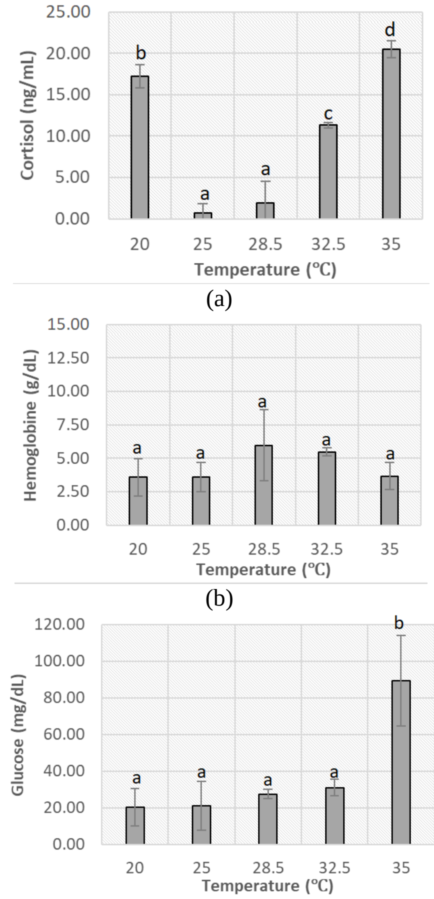

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Fig. 3 Stress responses of the Asian redtail catfish H. nemurus were observed on cortisol (a), hemoglobin (b), and glucose (c) levels exposed to different temperatures over 12 days. Letters indicate statistically significant differences between treatments ($P < 0.05$)

Table 5. Temperature tolerance test of the Asian redtail catfish H. nemurus over 12 days in the rearing tanks

Temperature treatment (℃)	Measured temperature during the experiment (℃)	Fish number	Total Length (cm)	Total Weight (g)	12-days acclimated?	LOE
15℃	15.00℃	12	12.23 ± 1.02	17.12 ± 3.53	LOE	12 fish LOE in 5 minutes
20℃	20.90 ± 1.84 ℃	12	11.75 ± 1.10	15.50 ± 3.75	LOE	7 fish LOE on 4th day
25℃	25.85 ± 0.48 ℃	12	11.75 ± 1.40	13.80 ± 4.49	Yes	-
28.5℃ (control)	28.53 ± 0.69 ℃	12	11.33 ± 1.05	13.00 ± 4.64	Yes	-
32.5℃	32.52 ± 0.67 ℃	12	11.73 ± 0.86	15.39 ± 3.29	Yes	-
35℃	35.12 ± 1.13 ℃	12	12.08 ± 0.75	16.19 ± 2.80	LOE	5 fish LOE on 4th day
40℃	40.00 ℃	12	12.22 ± 1.16	17.97 ± 6.15	LOE	12 fish LOE in 5 minutes

Note: LOE - loss of equilibrium

This is almost the same as compared to Asian catfish *Clarias batrachus*, which can live normally at the range temperature of 25 to 32℃ [15]. Temperatures above optimal limits have adverse impacts on fish health that affect the fish's survival, distribution, and metabolic processes.

As the fish is unable to adapt to fluctuating temperatures, this can affect the failure of physiological systems causing LOE and leading to mortality. Fish in tropical waters have different responses to temperature, but they can generally adapt to temperatures of 22-35℃ [29]. The limited physiological response of fish to stress caused by temperature can shape the distribution of different fish species known as limiting factors in the distribution of fish species [30]. This information is very useful to select a suitable location for the development of Asian redtail catfish farming. Stress response of fish exposed to extreme temperature leads to significant increase in glycemia, cortisol, and peroxidase activity [31]. Furthermore, there is a negative correlation between temperature and hemoglobin. Hemoglobin is found relatively lower as the water temperature rises to an extreme level outside its normal temperature range [32]. In general, hemoglobin levels decreased as compared to control treatment, although there is a hemoglobin decrease, there is no abnormal behavior identified in fish as the hemoglobin levels are still in the standard range [33]. Additionally, blood glucose levels generally increase with increasing water temperature. Changes in water temperature can increase the glucose requirement as an energy source to perform cell metabolism [34].

4. Conclusion

This research reveals that the domesticated Asian redtail catfish are able to be acclimated in a slightly brackish water environment (≤ 10 ppt), have more resilience in acidic than alkaline water (5.0 to 7.35), and can adjust in wide ranges of warm temperature (25℃ to 32.5℃). Tolerance of fish on salinity, pH, and temperature exposures indicated by different behavioral and physiological responses. As catfish acclimated to the environmental stressors experienced behavioral changes, cortisol level analysis is the best indicator to detect stress responses of the catfish. This can mitigate unpredictable environmental events and early warnings in the changes of environmental quality.

Information on fish tolerance and physiological responses to environmental stressors also would be beneficial to identify new areas of catfish culture selection and to improve water quality management in catfish aquaculture. This study recommends that the domesticated *H. nemurus* can be developed for the new catfish aquaculture candidate as it met a requirement to tolerance test on different water quality level which its responses was commonly similar compared to other existing aquaculture species. However, for a better understanding of optimum ranges of water quality on growth and survival of the catfish for aquaculture development, further research needs to be conducted in long-term exposures (>1 month) on the ranges of water quality in order to know the performance of the specific growth rate, feeding conversion rate and survival of the fish as main indicators of the successful aquaculture species.

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