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Comparative Osmoregulation Response of Common Carp (*Cyprinus carpio*) and Gourami (*Osphronemus gouramy*) Under Seawater Exposure

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Abstract: Homeostasis is an essential physiological process that functions to maintain the stability of an organism's internal conditions, primarily through osmoregulation mechanisms in aquatic animals. This study aims to: 1. Compare the physiological responses of osmoregulation between goldfish (*Cyprinus carpio*) and gourami fish (*Osphronemus gouramy*) after being given treatment in the form of exposure to seawater. 2. Increasing students' insight into animal physiology, especially osmoregulation material in fish. The method used was an experiment with two treatment groups, each group replicated 15 times. Data collection was conducted through direct observation of the fish's survival time and respiratory frequency. Data analysis was carried out using a t-test at the 5% significance level. The results showed that gourami had a higher average survival time (41.80 minutes) than goldfish (16.33 minutes). In contrast, goldfish showed a higher respiratory rate, indicating greater osmotic stress. Based on the t-test, a significant value of 0.00 <0.05 was obtained. This study concludes that there is a significant difference in survival between goldfish and gourami. Gourami fish have better osmoregulatory adaptation abilities than goldfish in high-salinity environments. The findings provide valuable insights into species-specific osmoregulatory adaptations to salinity stress and can serve as an effective learning resource for enhancing students' understanding of animal physiology and aquatic environmental adaptation.

Keywords: Freshwater Fish; Osmotic Stress; Osmoregulation; Physiological Adaptation; Salinity.

Introduction

Homeostasis is the ability of living things to maintain the stability of their internal body conditions within normal limits despite changes in the external environment. Physiologically, homeostasis involves regulating the balance of fluids, ions, *pH,* and body temperature through complex mechanisms, including hormonal and nervous system actions. Fluid balance is an important part of homeostasis and is essential for the survival of organisms [1]. This balance must be maintained to maintain optimal body conditions, because most of the body is composed of fluids, and even small changes can have a major impact on physiological functions [2]. One important mechanism that maintains this fluid balance is osmoregulation, the process of regulating water and ions in an organism's body.

Osmoregulation is a physiological process in aquatic organisms that maintains fluid balance and osmotic pressure, helping them remain stable despite changes in environmental conditions. In fish, osmoregulation is essential for maintaining ion and water concentrations so that metabolic processes, growth, and survival can proceed normally. This function is carried out by several main organs, such as gills, kidneys, and skin, where gills facilitate ion and gas exchange, kidneys regulate water and salt excretion, and skin helps limit the diffusion of substances into and out of the environment [7]. The relationship between osmoregulation and environmental salinity is close, because differences in salt content between the fish's body and its environment create an osmotic pressure that forces the fish to adjust. In freshwater fish, water tends to enter the body so that the fish must expel excess water and absorb ions, whereas in high salinity conditions, fish will lose water and must actively excrete salt [10]. Based on these differences in osmotic pressure, fish can be classified by habitat; freshwater fish, for example, have a unique osmoregulatory mechanism due to their low-salt environment.

Freshwater fish have unique physiological characteristics because they live in a hypotonic environment, where water tends to enter the body and ions exit by osmosis. To overcome this, freshwater fish absorb ions through their gills and excrete excess water through their kidneys as dilute urine. This mechanism maintains the body's fluid and electrolyte balance (homeostasis). However, increased salinity can disrupt this balance and cause physiological stress, even death, due to limited adaptive capacity. This condition becomes even more pronounced when freshwater fish are directly exposed to seawater with much higher salinity.

Water is the primary habitat for fish, which have different physical and chemical characteristics, especially between freshwater and seawater. The main difference lies in salinity, which affects osmotic pressure: seawater is hypertonic, while freshwater is hypotonic to fish body fluids. This condition causes water and ions to move by osmosis, so fish require osmoregulatory mechanisms to maintain internal balance [3]. When freshwater fish are exposed to seawater, their bodies tend to lose water and experience high osmotic pressure. Exposure to high salinity triggers a physiological

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response characterised by increased osmoregulatory activity in the gills, kidneys, and excretory system. This process requires a large amount of metabolic energy because fish must adjust the concentration of body fluids. If not optimal, the physiological balance will be disturbed, leading to osmotic stress. This stress can cause behavioral changes, impaired organ function, decreased immunity, and even death. Therefore, understanding the impact of seawater exposure is important in fisheries biology and aquaculture. One approach to understanding this response is to study freshwater fish such as carp and gourami, which differ in their physiological characteristics. Carp (*Cyprinus carpio*) is a freshwater fish that naturally lives at a salinity of 0 ppt and has the character of being easy to cultivate, but is a fish with a narrow salinity tolerance, where the best growth and survival rate occurs in freshwater conditions and decreases with increasing salinity up to 10 ppt. Meanwhile, the gourami (*Osphronemus gouramy*) is a native Indonesian fish of high economic value, with a large body size and strong reproductive and survival abilities, suggesting potential for broader environmental adaptation, even though it is generally classified as a freshwater fish. Based on these characteristics, gourami is thought to have a greater tolerance for environmental conditions than carp.

Research methods

Tools and materials were used in this research: stationery, 30 plastic buckets with a capacity of 2 liters, a mobile phone, and a stopwatch. Meanwhile, the materials were: 30 liters of seawater, gourami fish (*Osphronemus goramy*) and goldfish (*Cyprinus carpio*). Time and place of the research, conducted on Saturday, March 7, 2026, at Loang Baloq Beach, located in Tanjung Karang Village, Sekarbela District, Mataram City, West Nusa Tenggara Province. This research uses a 2-group experimental design: goldfish and gourami. Each treatment group was replicated 15 times. Each fish sample was exposed to seawater by being placed in a plastic bucket containing one liter of seawater. The release of fish on the treatment media was carried out simultaneously. Survival time was recorded for the treated fish samples until death. Data were analyzed by a different test, namely the t-test with a significance level of 5%.

Results and Discussion

The results of the study showed that goldfish (*Cyprinus carpio*) in seawater media survived an average of 16.33 minutes, while gourami (*Osphronemus goramy*) survived an average of 41.80 minutes. This significant difference indicates a difference in osmoregulatory capacity between the two species when suddenly exposed to a hypertonic environment. This is consistent with [3], which states that goldfish have a relatively narrow salinity tolerance and experience a drastic decrease in survival when salinity exceeds their tolerance limit. Based on Table 1, the average survival rates differ between goldfish (16.33) and gourami (41.80). There is also a difference in the respiratory rate between goldfish (178.73) and gourami (141.2).

Table 1. Observation Results of Survival and Respiration Rate of Goldfish (*Cyprinus carpio*) and Gurami Fish (*Osphoronemus goramy*), Time Unit Minutes

Group treatment	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	Average
Resilience live goldfish	16	18	18	20	21	18	14	19	17	12	21	8	8	17	18	16.33
Respiratory rate goldfish	145	162	138	178	155	190	210	185	172	168	195	230	218	175	160	178.73
Resilience live gourami fish	38	38	42	42	34	48	42	39	48	44	45	47	35	37	48	41.80
Respiratory rate gourami fish	112	128	105	140	118	152	165	142	135	148	158	172	168	145	130	141.2

Table 2. Results of the t-test of Survival Between Goldfish (*Cyprinus carpio*) and gourami fish (*Osphoronemus goramy*)

Variabel	Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Difference	Lower	Upper
Survival Time (Equal variances assumed)	0.791	0.381	-15.543	28	0.000	-2.547	163.843	-2.882	-2.211
Survival Time (Equal variances not assumed)	–	–	-15.543	27.4	0.000	-2.547	163.843	-2.882	-2.211

The ability of freshwater fish to survive at high salinity is highly dependent on the capacity of gill ionocyte cells to carry out active ion transport efficiently, and differences between species reflect differences in the expression of ion transporter genes possessed by each type of fish [4]. The inability of goldfish to survive longer indicates that the osmoregulatory system of this species is unable to compensate for the very high osmotic pressure of seawater (around 35 ppt) in a short time.

Respiratory rate data showed an inverse relationship with survival. Goldfish had an average respiratory rate of 178.73 breaths/minute, significantly higher than that of gourami (141.20 breaths/minute). The higher respiratory rate in goldfish reflects a more severe physiological stress response due to the osmotic pressure of seawater. The increased respiratory rate is closely related to the increased energy requirements of active osmoregulatory mechanisms, particularly ion transport through the gills [5]. The effect of differences in salinity on the rate of oxygen consumption of koi carp (*Cyprinus carpio*) also found that increasing salinity was positively correlated with increasing respiratory rate, reflecting the increased oxygen demand to support the Na+/K+-ATPase ion pump in the gill ionocyte cells [6]. Thus, a high respiratory rate in goldfish not only indicates stress but also reflects the fish's maximum effort to maintain ionic homeostasis, which ultimately cannot be sustained for long.

In addition to physiological mechanisms involving organs such as gills and kidneys, osmoregulatory responses are also influenced by changes at the cellular and biochemical levels. Changes in salinity cause reorganization of the structure of gill epithelial cells, especially in chloride cells that play a role in ion transport [7]. This adaptation involves an increase in the number and activity of ionocyte cells to maintain ionic balance in the fish's body. However, under conditions of acute osmotic stress, this adaptation ability is often suboptimal, leading to rapid internal imbalance.

Furthermore, the hormone cortisol plays an important role in the adaptation process to changes in salinity [8]. Cortisol enhances fish's ability to regulate ion balance by stimulating Na+/K+-ATPase activity. However, excessive increases in cortisol levels can actually cause physiological disorders such as a decreased immune system and increased susceptibility to environmental stress.

On the energy metabolism side, osmoregulation requires significant energy because it involves active ion transport against a concentration gradient [9]. Therefore, fish with greater metabolic efficiency tend to have a higher tolerance to salinity changes. This may explain why gourami survived longer than goldfish in this study.

Furthermore, the expression of ion transporter proteins in the gills increases significantly when fish are exposed to high-salinity environments [10]. These proteins function in the excretion of excess ions and in maintaining body fluid balance. However, this increase has a limit, so that under extreme conditions, osmoregulatory failure still occurs.

Osmotic stress also triggers protective responses at the molecular level, such as the production of organic osmolytes (e.g., taurine and betaine), which help maintain protein and cell membrane stability [11]. This mechanism is an important form of short-term adaptation, but it is not sufficient to sustain survival if osmotic stress is severe and prolonged.

When freshwater fish are transferred to seawater, their bodies face hypertonic conditions that cause water to leave the tissues by osmosis while salt ions enter by diffusion. This condition forces osmoregulatory organs, especially the gills, kidneys, and intestines, to work more intensively to eliminate excess ions and maintain body fluid volume [12]. Gills play a central role in the excretion of Na+ and Cl^- ions via chloride cells, which are supported by the Na+/K+-ATPase enzyme. The activity of this enzyme requires a large amount of ATP energy and directly contributes to increased metabolic and respiration rates [13]. Gourami fish that exhibit lower respiratory rates and longer survival times may have more adaptive gill ionocytes, which operate more efficiently under hyperosmotic conditions. [14] stated that the adaptability of carp to changes in salinity is limited, and sudden exposure to high salt levels can cause rapid failure of osmoregulatory mechanisms. Meanwhile, the kidneys of fish exposed to high salinity shift from producing large amounts of dilute urine (in freshwater conditions) to producing small amounts of concentrated urine, as an effort to conserve body water [2].

The ability of gourami fish to survive longer in seawater (average 41.80 minutes) compared to carp indicates a relatively better physiological adaptation capacity. This is in line with the biological character of gourami as a fish with a broad environmental tolerance, including to changes in water quality [15]. Gourami fish are still able to maintain blood glucose and hemoglobin levels within normal limits at salinities up to 6 ppt, which indicates the presence of an active physiological compensation mechanism [16]. Strengthens this finding, where tambakan fish (*Helostoma temminckii*) which is still in the same family (Osphronemidae) as gourami showed a better physiological response at a salinity of 3 ppt, with a survival rate of 82% and an optimal specific growth rate [17]. Blood parameters such as glucose, hematocrit, hemoglobin, and erythrocyte count also showed a positive correlation with the environmental osmotic gradient, indicating that fish from the Osphronemidae family have a more adaptive osmoregulatory mechanism to changes in salinity compared to carp (Cyprinidae) [17]. Furthermore, swamp gourami (*Trichogaster pectoralis*) which is also in the same family as gourami shows that the isotonic point (osmotic pressure balance with the environment) occurs at a salinity of around 12‰ (345.67 mOsm) [1]. This means that at salinities below 12‰, fish from the Osphronemidae family are still able to maintain osmotic balance without expending excessive energy, which explains why gourami in this study were able to survive longer (41.80 minutes) in seawater compared to goldfish, which only lasted 16.33 minutes. Gourami exposed to 10 ppt salinity for 30 days showed a 2.5-fold increase in gill Na+/K+-ATPase activity compared to freshwater controls, as a compensatory mechanism to excrete excess ions [18]. Furthermore, at 20 ppt salinity, the activity of this enzyme decreased drastically due to limited metabolic energy, leading to ion accumulation in the blood and disrupting homeostasis. This finding explains that although gourami has a better adaptation capacity, there is still a salinity limit that cannot be exceeded.

However, at much higher seawater salinities (around 30–35 ppt), this adaptability still has limits. Prolonged osmotic stress will activate the hypothalamic-pituitary-interrenal (HPI) axis, which produces cortisol. Cortisol plays a role in energy mobilization as well as modulating gill membrane permeability, but if its production continues without recovery, immunosuppression and organ failure will occur [19]. Thus, the difference in resilience between the two species reflects differences in hormonal regulatory capacity and ion-transport efficiency in response to acute osmotic stress.

At the molecular level, salinity stress is known to trigger increased expression of ion transporter genes such as Na+/K+-ATPase (nka) and aquaporin (aqp3), which play a role in maintaining ion and water balance in gill tissue. [20] explained that fish with higher salinity tolerance tend to show more stable regulation of osmoregulatory gene expression, as well as more efficient adjustment of osmoprotectant metabolites. This is thought to be one of the factors underlying gourami fish's ability to live longer than goldfish.

Based on Table 2, the T-test results show a statistically significant difference in survival between goldfish (Mean = 16.33; SD = 4.13) and gourami (Mean = 41.80; SD = 4.81) at the 5% level. This 25.47-minute difference confirms that the osmoregulatory abilities of the two species differ significantly when exposed to hypertonic seawater conditions. The relatively low standard deviation values in both groups indicate the consistency of physiological responses within each species. The variation in the data can be attributed to individual physiological conditions of the fish, such as body size, health status, and the readiness of the endocrine system at the time of treatment. Ecologically, these results confirm that both goldfish and gourami are not euryhaline, capable of surviving across a wide range of salinities, but rather stenohaline, limited to freshwater [21]. This significant difference has important implications for aquaculture: sudden exposure to high salinity is fatal and must be avoided, especially for goldfish, whose adaptive capacity is more limited.

Homeostasis is a condition of internal body balance that must be maintained for normal metabolism. Fluid balance is a key component of homeostasis that is greatly influenced by environmental dynamics, especially salinity [5]. Disruptions in body fluid regulation will trigger a biochemical cascade that worsens the overall physiological condition [22]. In fish exposed to seawater, cellular dehydration from osmotic water loss increases intracellular ion concentrations, ultimately inhibiting the function of enzymes and structural proteins. This condition is exacerbated by the excessive influx of Na+ and Cl^- ions, which disrupts cell membrane potential and nerve function. The molecular response to osmotic stress involves the activation of heat shock proteins and osmosensitive transcription factors that attempt to protect the integrity of cell proteins, but this response has limits that depend on the intensity and duration of the stress [23-24]. Thus, the death of fish in this study was a direct consequence of homeostasis failure triggered by the inability of the osmoregulatory system to maintain stable internal conditions under extreme seawater osmotic pressure.

The findings of this study have significant practical relevance in the management of freshwater fish farming. Understanding the salinity tolerance limits of these two species is crucial to prevent mass mortality in culture ponds due to seawater intrusion, a risk that is increasing with climate change and sea-level rise. Abrupt changes in salinity are far more dangerous than gradual changes because they do not allow time for organisms to undergo physiological acclimatization [25-26]. Further research on the potential for gradual acclimatization of these two species to low salinity (5–10 ppt) could open up opportunities for diversification of aquaculture habitats into brackish waters, particularly for gourami, which exhibits better tolerance. Furthermore, the results of this study are relevant to the development of live fish transportation protocols, in which seawater contamination or salinity fluctuations during shipping must be strictly controlled to ensure the safety and health of the transported fish. Information on respiratory rate as a bioindicator of stress can also serve as a parameter for non-invasive field monitoring of fish health.

Conclusion

Based on the research results, data analysis, and discussion, it can be concluded that there are significant differences in osmoregulatory ability between goldfish (*Cyprinus carpio*) and gourami (*Osphronemus gouramy*) when exposed to a hypertonic seawater environment. Gourami fish had a longer survival time, averaging 41.80 minutes, compared to goldfish, which only survived 16.33 minutes. Furthermore, the higher respiration rate of goldfish indicates a greater level of osmotic stress compared to gourami fish. This indicates that gouramis have a better physiological adaptation to salinity changes than goldfish. Overall, this study confirms that osmoregulatory mechanisms play a crucial role in maintaining fish homeostasis during environmental changes, particularly salinity. The inability of freshwater fish to adapt quickly to high salinity conditions can lead to physiological disorders and even death. Therefore, the results of this study have important implications for aquaculture, particularly for water quality management and the prevention of sudden salinity changes that can be detrimental to fish survival.

Author's Contribution

I.W. Merta: conceptualization, methodology, investigation, data collection, formal analysis, data interpretation. Kusmiyati: review and editing, supervision. All authors have read and agreed to the published version of the manuscript.

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