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# Dynamics of Dissolved Oxygen Release from Hydrogen Peroxide Under Different Temperature Regimes in Closed System

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**Abstract**

Dissolved oxygen (DO) is an important parameter in aquaculture systems as it directly influences water quality stability and the biological activity of aquatic organisms. This study aimed to evaluate the dynamics of dissolved oxygen resulting from hydrogen peroxide decomposition under different temperature conditions in a closed system. The experiment was conducted at two temperature regimes, namely 25°C and room temperature (27–28°C), using hydrogen peroxide doses of 0 mL/L, 0.025 mL/L, 0.050 mL/L, and 0.075 mL/L. Observations were carried out over a 24-hour period, with measurements recorded every two hours. The results showed that hydrogen peroxide increased dissolved oxygen concentrations during the first four hours of observation under both temperature conditions. Dissolved oxygen remained more stable at 25°C than at room temperature (27–28°C), indicating greater oxygen retention at lower temperatures. In media containing tilapia, dissolved oxygen increased more rapidly during the initial observation period, suggesting that biological activity accelerated hydrogen peroxide decomposition. However, dissolved oxygen gradually declined over time due to oxygen consumption by fish and associated microorganisms. Water temperature remained relatively stable throughout the experiment, whereas pH decreased after 24 hours, particularly in treatments containing fish. These findings indicate that temperature and biological activity play key roles in regulating dissolved oxygen dynamics and oxygen release from hydrogen peroxide. Therefore, hydrogen peroxide shows potential as an alternative oxygen source in closed aquatic systems, although its effectiveness depends on environmental temperature and biological activity.

Keywords: dissolved oxygen, hydrogen peroxide, temperature.

## INTRODUCTION

Dissolved oxygen (DO) is a key parameter in aquaculture systems that plays a direct role in metabolic processes, physiology, and water quality stability of aquatic organisms. In closed systems, DO availability poses a major challenge due to limited gas exchange with the external environment, while aquatic biota continuously consumes oxygen (Martins *et al*., 2021). These conditions can lead to a rapid decline in oxygen levels, necessitating oxygen supplementation strategies to maintain system stability and prevent hypoxia.

Hydrogen peroxide has been extensively studied in aquaculture systems due to its ability to decompose into water and oxygen (Taylor and Ross, 1988; Bögner *et al*., 2021; Wood *et al*., 2021; Shabanov *et al*., 2024)

without leaving residues (Yanong, 2022; Maghribfa *et al*., 2023; Shabanov *et al*., 2024). This decomposition reaction can serve as an alternative oxygen source in aquatic systems (Wood *et al*., 2021; Bui *et al*., 2025). However, the effectiveness of hydrogen peroxide is strongly influenced by environmental conditions such as temperature, organic matter content, and biological activity in aquatic systems (Bögner *et al*., 2021).

Temperature is a key factor regulating dissolved oxygen dynamics. An increase in temperature can reduce the solubility of oxygen in water while simultaneously increasing the metabolic rate of aquatic organisms, thereby elevating their oxygen demand. As a result, dissolved oxygen tends to decrease at higher temperatures; conversely, at lower temperatures, oxygen solubility is higher and dissolved oxygen levels are more stable (Boyd and Tucker, 2020; Martins *et al*., 2021; Ma *et al*., 2025).

Although various studies have examined the role of hydrogen peroxide as an oxygen source and the effect of temperature on dissolved oxygen dynamics, information regarding the combined effects of temperature on dissolved oxygen derived from hydrogen peroxide decomposition in closed systems remains limited. Therefore, this study aims to evaluate the dynamics of dissolved oxygen release from hydrogen peroxide decomposition at different temperatures in a closed system.

## MATERIALS AND METHODS

### Location and time of research

This study aimed to evaluate changes in dissolved oxygen concentrations resulting from hydrogen peroxide decomposition at different temperatures under closed-system conditions over a 24-h period. The experiment was conducted from 17 October to 30 December 2024 at the Aquaculture Laboratory, Faculty of Fisheries and Marine Sciences, Diponegoro University.

### Research Design

This study was conducted as an experimental study to evaluate changes in dissolved oxygen release from hydrogen peroxide at different temperatures under closed-system conditions. Four hydrogen peroxide doses (D1= 0 ml/L; D1= 0.025 ml/L; D2= 0.050 ml/L; D3= 0.075 ml/L) were tested, each with three replicates. Dissolved oxygen concentrations were measured every two hours for 24 h. The data were analyzed descriptively and presented in tables and figures.

The study comprised two experiments. The first experiment evaluated dissolved oxygen release resulting from hydrogen peroxide decomposition in water without fish, whereas the second experiment assessed dissolved oxygen release in water containing fish under the same experimental conditions. The fish used in the second experiment were tilapia (*Oreochromis niloticus*) with a total length of 7–9 cm and a body weight of 6–9 g.

### Observation of Dynamics Dissolved Oxygen

The optimal dissolved oxygen requirement for tilapia ranges from 5–7 mg/L (Ambarwati and Tholibah, 2021). To evaluate the increase in dissolved oxygen provided by hydrogen peroxide as an oxygen source, dissolved oxygen concentrations were monitored using 35% hydrogen peroxide at doses of 0 mL/L, 0.025 mL/L, 0.050 mL/L, and 0.075 mL/L over a 24-h observation period. Dissolved oxygen concentrations were recorded every 2 h.

The experiment was conducted using plastic bags (50 × 75 cm) containing 5 L of water. Hydrogen peroxide was added using a 1-mL syringe according to the predetermined dose. During application, the plastic bag was opened only slightly to minimize oxygen loss. A dissolved oxygen meter was then inserted and secured using a rubber band. Observations were carried out under two temperature conditions, namely 25°C and room temperature (27–28°C), to evaluate dissolved oxygen dynamics under different thermal conditions. An identical procedure was used in the experiment with Nile tilapia (*Oreochromis niloticus*), with the only difference being the addition of fish to the transport medium.

### Water Quality

Temperature and pH were monitored as supporting water quality parameters. Measurements were conducted using a calibrated water quality meter at 0 h and 24 h to evaluate changes in water conditions during the experimental period.

### Data analysis

The data were analyzed descriptively. Dissolved oxygen concentrations were presented as mean values from three replicates and illustrated using tables and figures to describe the temporal dynamics of oxygen release under different temperature regimes.

## RESULTS AND DISCUSSION

### Results

### Dissolved Oxygen Dynamics at Different Temperatures

At 25°C, dissolved oxygen concentrations in the hydrogen peroxide treatments (D1, D2, and D3) increased during the first 4 h of observation and remained relatively stable until the end of the 24-h observation period. In contrast, the treatment without hydrogen peroxide (D0) showed a sharp decline in dissolved oxygen during the first 4 h, followed by a gradual decrease thereafter.

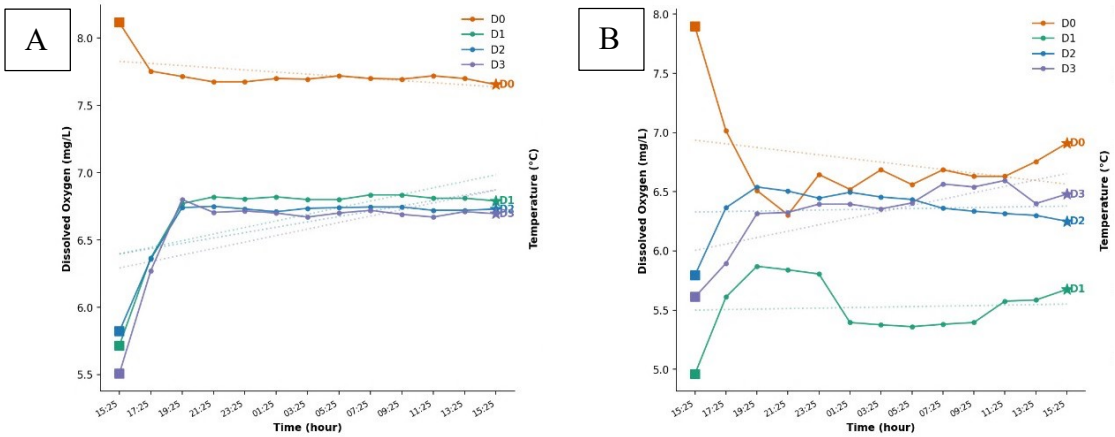


Figure 1. Histogram of dissolved oxygen dynamics at different temperatures.
(A) at 25°C, (B) at room temperature (27–28°C).

At room temperature (27–28°C), dissolved oxygen concentrations in the hydrogen peroxide treatments (D1, D2, and D3) also increased during the first 4 h of observation. However, dissolved oxygen levels tended to fluctuate more than those observed at 25°C. In the treatment without hydrogen peroxide (D0), dissolved oxygen concentrations continued to decline throughout the observation period. The lower stability of dissolved oxygen at room temperature may be related to the reduced oxygen solubility of water at higher temperatures, which limits oxygen retention, particularly at lower hydrogen peroxide doses.

**Dissolved Oxygen Dynamics in the Presence of Tilapia**

Dissolved oxygen (DO) levels across all treatments exhibited a decreasing trend over the observation period. As shown in Figure 1(A), DO values in treatment D0 were consistently higher than those in the other treatments. A more pronounced decline was observed at room temperature (27–28°C) (Figure 1(B)) toward the end of the observation period. The highest DO values at both temperatures were recorded in D0, whereas treatments D1, D2, and D3 showed relatively similar patterns throughout the experiment. At 25°C, DO in D1 showed a temporary increase midway through the observation period before decreasing again.

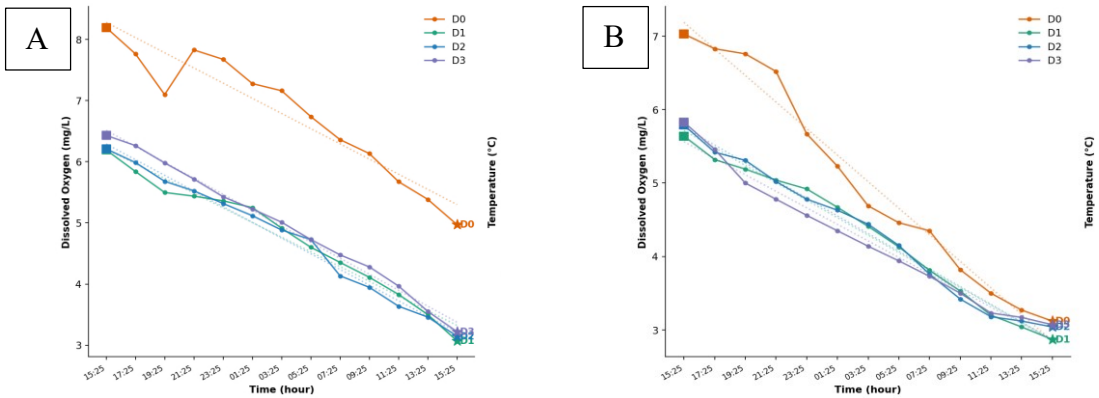


Figure 2. Histogram of dissolved oxygen dynamics in the presence of tilapia.
(A) at 25°C, (B) at room temperature (27–28°C).

**Water Quality**

Water quality (Table 2) showed that temperature and pH under both 25°C and room temperature treatments remained relatively stable throughout the 24-hour observation period, with no pronounced fluctuations. This suggests that the application of hydrogen peroxide at doses of 0-0.075 mL/L did not significantly affect water temperature or pH. The observed stability may be attributed to the relatively low concentrations of hydrogen peroxide used in this study.

Table 2. Water Quality Parameters Oxygen Dynamics at Different Temperatures

| Without Tilapia | | | | |
|---|---|---|---|---|
| Treatment | 0 Hour | | 24 Hour | |
| | Temperature (25°C) | pH | Temperature (25°C) | pH |
| D0 | 25.27 ± 0 | 7.63 ± 0.26 | 25.37 ± 0.17 | 7.62 ± 0.05 |
| D1 | 25.37 ± 0 | 7.62 ± 0.07 | 25.43 ± 0.26 | 7.62 ± 0.11 |
| D2 | 25.27 ± 0.1 | 7.67 ± 0.10 | 25.40 ± 0 | 7.58 ± 0.26 |
| D3 | 25.33 ± 0.05 | 7.70 ± 0.17 | 25.40 ± 0.15 | 7.68 ± 0.05 |
| Treatment | 0 Hour | | 24 Hour | |
| | Temperature (27–28°C) | pH | Temperature (27–28°C) | pH |
| D0 | 28.15 ± 0.05 | 7.71 ± 0.11 | 28,20 ± 0 | 7.70 ± 0,07 |
| D1 | 28.75 ± 0.05 | 7.64 ± 0.05 | 28.45 ± 0.11 | 7.62 ± 0.15 |
| D2 | 28,45 ± 0.14 | 7.65 ± 0 | 28,70 ± 0.07 | 7.65 ± 0.11 |
| D3 | 28,60 ± 0.15 | 7.68 ± 0.10 | 28,45 ± 0.28 | 7.66 ± 0.07 |

*Values represent mean ± standard deviation

Water quality during dissolved oxygen dynamics observation with tilapia showed relatively minor fluctuations in temperature over the 24-hour period, at both 25°C and room temperature conditions. In contrast, pH decreased in several treatments after 24 hours, a pattern observed under both temperature regimes. Overall, the presence of tilapia tended to reduce pH, while water temperature remained relatively stable.

Table 3. Water Quality Parameters Oxygen Dynamics in the Presence of Tilapia

| With Tilapia | | | | |
|---|---|---|---|---|
| Treatment | 0 Hour | | 24 Hour | |
| | Temperature (25°C) | pH | Temperature (25°C) | pH |
| D0 | 25.30 ± 0.05 | 7.63 ± 0.05 | 25.45 ± 0.05 | 7.20 ± 0 |
| D1 | 25.55 ± 0.05 | 7.77 ± 0 | 25.35 ± 0.05 | 7.23 ± 0.05 |
| D2 | 25.45 ± 0.05 | 7.67 ± 0.05 | 25.40 ± 0 | 7.60 ± 0.26 |
| D3 | 25.50 ± 0.05 | 7.70 ± 0 | 25.40 ± 0.05 | 7.60 ± 0.26 |
| Treatment | 0 Hour | | 24 Hour | |
| | Temperature (27–28°C) | pH | Temperature (27–28°C) | pH |
| D0 | 27,95 ± 0.05 | 7.63 ± 0.05 | 28,30 ± 0 | 7.33 ± 0.05 |
| D1 | 28,95 ± 0.07 | 7.68 ± 0.17 | 28,70 ± 0 | 7.23 ± 0.26 |
| D2 | 28,65 ± 0.07 | 7.73 ± 0 | 28,50 ± 0.07 | 7.60 ± 0.1 |
| D3 | 28,80 ± 0 | 7.64 ± 0.01 | 28,60 ± 0.28 | 7.57 ± 0.13 |

*Values represent mean ± standard deviation

**Discussion**

Temperature is one of the key factors influencing the effectiveness of hydrogen peroxide as an oxygen source. As water temperature increases, oxygen solubility decreases, reducing the capacity of water to retain dissolved oxygen. Consequently, dissolved oxygen concentrations tend to be more stable at lower temperatures, such as 25°C, than at room temperature (27–28°C). Temperature directly affects dissolved oxygen dynamics, as higher temperatures promote the release of oxygen from the water column and reduce its retention capacity (Post *et al.,* 2018; Boyd *et al*., 2020). Higher fluctuations in dissolved oxygen at room temperature (27–28°C) indicate that increased temperature reduces the ability of water to retain dissolved oxygen while simultaneously increasing the oxygen demand of organisms and microorganisms within the system. As a result, oxygen generated from hydrogen peroxide decomposition is consumed more rapidly, leading to lower dissolved oxygen stability. These findings are consistent with those reported by Powell and Scolding (2016), Martins *et al*. (2021), and Ma *et al*. (2025), who demonstrated that environmental conditions, particularly temperature, play a significant role in determining the effectiveness of oxidizing agents and the stability of water quality in closed aquaculture systems.

The addition of hydrogen peroxide in this study resulted in an increase in dissolved oxygen during the first four hours of observation. This increase was attributed to the decomposition of hydrogen peroxide into water and oxygen, a mechanism that has been widely utilized as an alternative oxygen source in aquaculture systems (Bögner *et al*., 2021; Wood *et al*., 2021; Bui *et al.,* 2025). Although the differences in dissolved oxygen enhancement among the tested doses were relatively small, hydrogen peroxide was able to provide supplemental oxygen to the water throughout the observation period. However, increasing the dose did not necessarily result in a proportional increase in dissolved oxygen concentration, as the effectiveness of oxygen

release is influenced by environmental factors such as temperature, organic matter content, and biological activity within the system. Similar findings have been reported by Bögner *et al*. (2021) and Kashem *et al*. (2023), who demonstrated that the effectiveness of hydrogen peroxide in aquatic environments depends on its interaction with surrounding environmental conditions.

The differences in dissolved oxygen dynamics between the two observations (Figures 1 and 2) suggest different rates of hydrogen peroxide decomposition. In Figure 1, dissolved oxygen concentrations increased gradually during the first four hours of observation, whereas in Figure 2, an increase in dissolved oxygen was observed as early as the first hour. This pattern indicates that oxygen release from hydrogen peroxide occurred more rapidly in media containing fish. This phenomenon may be associated with the presence of catalase and peroxidase enzymes in fish tissues and mucus, as well as microbial communities associated with fish in the aquatic environment, which can accelerate the decomposition of hydrogen peroxide (Song *et al*., 2023). Fish mucus also serves as a habitat for microorganisms and contains various biologically active compounds that may enhance interactions between hydrogen peroxide and the aquatic environment (Reverter *et al*., 2018; Dash *et al*., 2018). Consequently, dissolved oxygen increased more rapidly in treatments containing fish than in those without fish.

The pH values in all treatments showed a slight decline after 24 h of observation, particularly in treatments containing fish. This pattern suggests that the presence of fish influenced changes in water chemistry throughout the experimental period. One of the primary causes of the pH decrease is the accumulation of carbon dioxide ($CO_2$) produced through fish respiration. During respiration, oxygen is consumed for energy production, while carbon dioxide is released as a metabolic byproduct (Shartau *et al*., 2020; Erikson *et al*., 2022). In a closed system, the released $CO_2$ accumulates in the water and reacts with water molecules to form carbonic acid, which subsequently lowers pH. In addition to fish respiration, microbial activity associated with the decomposition of organic matter derived from fish excretion may further contribute to $CO_2$ production through microbial respiration (Colt and Watten, 2019). Although a decrease in pH was observed, the values recorded in this study remained within the neutral range, indicating that the buffering capacity of the system was sufficient to maintain overall pH stability during the observation period.

## Conclusion

The addition of hydrogen peroxide increased dissolved oxygen concentrations in a closed system. Dissolved oxygen remained more stable at 25°C than at room temperature (27–28°C), indicating that temperature influences the effectiveness of hydrogen peroxide as an oxygen source. The presence of fish accelerated the increase in dissolved oxygen during the early stages of the observation period, suggesting that biological activity may enhance the decomposition of hydrogen peroxide. However, dissolved oxygen concentrations gradually declined over time due to oxygen consumption by fish and associated microorganisms. Overall, temperature and biological activity were the primary factors influencing the dynamics of dissolved oxygen release from hydrogen peroxide in a closed system.

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