



## Optimizing *Ulva ohnoi* cultivation in biofloc systems: Influence of salinity

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### ABSTRACT

This study evaluated the salinity tolerance of the macroalga *Ulva ohnoi* cultivated in a biofloc system over a 14-day period. Five salinity treatments (10, 15, 20, 25, and 30‰) were tested, using 40-L tanks. Algae were acclimated to the target salinities before the cultivation phase and stocked at the density of 2 g·L<sup>-1</sup>. Water quality parameters (ammonia, nitrite, nitrate, orthophosphate, alkalinity, and pH), biomass gain, daily growth rate, phenolic compounds, chlorophyll, and carotenoids were evaluated. Water quality remained within acceptable ranges across treatments, although alkalinity showed significant differences. Complete mortality of *U. ohnoi* was observed at 10‰, and reduced growth was recorded at 15‰. In contrast, salinities of 20, 25, and 30‰ supported higher biomass gains and daily growth rates, with no significant differences in antioxidant compound concentrations among these treatments. Growth was significantly higher at salinities of 20–30‰, with biomass gains of 318–400 g and daily growth rates of 5.4–6.4% day<sup>-1</sup>, whereas at 15‰ biomass gain reached only ~111 g and growth rate ~1.2% day<sup>-1</sup>. These findings highlight the potential of *U. ohnoi* for integration into low-salinity biofloc systems and multitrophic aquaculture strategies, contributing to sustainable aquaculture practices by recycling nutrients and producing valuable biomass.

**Keywords:** Salinity tolerance; Seaweed; Biomass production; Antioxidant compounds; Integrated aquaculture.

### Otimização do cultivo de *Ulva ohnoi* em sistemas de bioflocos: Influência da salinidade

### RESUMO

Este estudo avaliou a tolerância à salinidade da macroalga *Ulva ohnoi* cultivada em um sistema de bioflocos ao longo de um período de 14 dias. Foram testados cinco tratamentos de salinidade (10, 15, 20, 25 e 30‰), utilizando tanques de 40 L. As algas foram aclimatadas às salinidades-alvo antes da fase de cultivo e estocadas na densidade de 2 g·L<sup>-1</sup>. Foram avaliados os parâmetros de qualidade da água (amônia, nitrito, nitrato, ortofosfato, alcalinidade e pH), o ganho de biomassa, a taxa de crescimento diário, compostos fenólicos, clorofila e carotenoides. A qualidade da água permaneceu de acordo com as faixas aceitáveis em todos os tratamentos, embora a alcalinidade tenha apresentado diferenças significativas. Mortalidade total de *U. ohnoi* foi observada em 10‰, e crescimento reduzido foi registrado em 15‰. Em contraste, as salinidades de 20, 25 e 30‰ proporcionaram maiores ganhos de biomassa e taxas de crescimento diário, sem diferenças significativas nas concentrações de compostos antioxidantes entre esses tratamentos. O crescimento foi significativamente maior nas salinidades de 20–30‰, com ganhos de biomassa entre 318–400 g e taxas de crescimento diário de 5,4–6,4% dia<sup>-1</sup>, enquanto em 15‰ o ganho de biomassa atingiu apenas ~111 g e a taxa de crescimento ~1,2% dia<sup>-1</sup>. Esses resultados destacam o potencial de *U. ohnoi* para integração em sistemas de bioflocos de baixa salinidade e em estratégias de aquicultura multitrófica, contribuindo para práticas aquícolas sustentáveis por meio da reciclagem de nutrientes e da produção de biomassa de valor agregado.

**Palavras-chave:** Tolerância à salinidade; Macroalga; Produção de biomassa; Compostos antioxidantes; Aquicultura integrada.

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## INTRODUCTION

The genus *Ulva* is among the most predominant in marine and estuarine environments (Kraft et al., 2010). Recognized as cosmopolitan, *Ulva* species occur across marine ecosystems, intertidal zones, estuaries, and brackish waters (Simon et al., 2022). Characterized by an opportunistic growth strategy, these seaweeds exhibit remarkable adaptability to a wide range of climatic and ecological conditions, making them well-suited for cultivation across diverse environments (Ben-Ari et al., 2014; Sheppard et al., 2023).

*Ulva* species have attracted significant interest for applications in food production, animal feed, pharmaceuticals, and cosmetics, largely due to their high nutritional value, including proteins, vitamins, minerals, amino acids, and polyunsaturated fatty acids (Legarda et al., 2021b; Moustafa & Eladel, 2016). Among these, *Ulva ohnoi*, originally described from Japan and currently invasive in several regions, stands out for its biochemical composition and potential industrial applications.

Some *Ulva* species are highly tolerant to adverse environmental conditions, including prolonged periods of light deprivation (Santelices et al., 2002), wide salinity ranges (0.5–49‰) (Rybak, 2015), and nutrient variability (Luo et al., 2012). In areas influenced by estuarine dynamics and tides, *Ulva* species experience environmental fluctuations such as changes in salinity driven by rainfall, solar exposure, and tidal cycles (Simon et al., 2022). Adaptive mechanisms allow these seaweeds to acclimate to both low and high salinity levels. Taylor et al. (2001) reported that *Ulva curvata*, *Ulva rigida*, *Ulva compressa*, and *Ulva linza* tolerate salinities from 3 to 34‰, with optimal growth between 6.8 and 27‰.

*Ulva* species are also known for rapid biomass accumulation, achieving growth rates up to 30% per day and displaying efficient uptake of dissolved nutrients such as nitrogen and phosphorus (Naldi & Wheeler, 2002; Simon et al., 2022). Nitrogen is absorbed preferentially as ammonia and nitrate, with studies on *Ulva lactuca* showing higher growth rates when ammonia is the primary nitrogen source (Ale et al., 2011). Phosphorus is mainly absorbed as orthophosphate, and its availability can limit seaweed growth, particularly under nitrogen-limited conditions (Lobban & Harrison, 1994).

This high nutrient uptake capacity makes *Ulva* particularly suitable for integration into aquaculture systems characterized by nutrient accumulation, such as biofloc technology (BFT). In BFT systems, intense microbial activity promotes the conversion of organic nitrogen into nitrate through chemoautotrophic nitrification, leading to progressive nitrate accumulation in

the water column (Kuhn et al., 2010). Excessive nitrate and phosphorus concentrations may impair animal performance, compromise water quality, and increase the risk of eutrophication when effluents are discharged untreated.

In this context, the application of integrated multitrophic aquaculture (IMTA) represents an effective strategy to recycle dissolved nutrients by incorporating extractive species capable of assimilating nitrogen and phosphorus into valuable biomass (Chopin et al., 2001; Legarda et al., 2021a; Morais et al., 2023). Macroalgae play a central role in IMTA systems due to their high nutrient removal efficiency and protein-rich biomass production (Alamrousi et al., 2022; Robertson-Andersson, 2003).

An additional operational challenge is that many BFT production systems operate at low or moderate salinity to accommodate euryhaline and freshwater species, such as Nile tilapia (*Oreochromis niloticus*), freshwater prawns (*Macrobrachium rosenbergii*), and inland or low-salinity culture of marine shrimp (*Litopenaeus vannamei*). However, the availability of macroalgae capable of maintaining high productivity and physiological stability under low-salinity BFT conditions remains limited.

Given its demonstrated salinity tolerance and physiological plasticity, *U. ohnoi* emerges as a promising candidate for integration into low-salinity IMTA systems coupled with BFT. Nevertheless, its specific salinity tolerance thresholds and performance under biofloc conditions are still poorly defined.

Therefore, this study aimed to define the salinity tolerance range and growth performance of the green macroalga *U. ohnoi* under biofloc conditions, addressing the current lack of information regarding its physiological limits in low-salinity systems and evaluating its potential as a bioextractive component for nutrient removal in integrated multitrophic aquaculture.

## MATERIAL AND METHODS

### Study site

The experiment was carried out at the Marine Shrimp Laboratory, which is part of the Aquiculture Department de of the Universidade Federal de Santa Catarina, located in Florianópolis, SC, Brazil (27.58,207° S, 48.43,958° W).

### Biological material

Seaweed specimens of *U. ohnoi* were collected from the sedimentation pond of the Marine Molluscs Laboratory, Florianópolis, SC, Brazil. All samples were thoroughly rinsed with filtered seawater to remove epiphytes, sediments, and associated fauna.

## Experimental design

The experiment was carried out in a greenhouse and consisted of five salinity treatments (10, 15, 20, 25, and 30‰), each with three replicates, totaling 15 experimental units. Each unit corresponded to a white rectangular tank with a useful volume of 40 L used for macroalgae cultivation.

Initially, *U. ohnoi* thalli was acclimated for 14 days in the experimental tanks. During the first 10 days, tanks were filled with 60% of filtered biofloc water (300-micron mesh) and completed with seawater to achieve a salinity of 30‰ across all units. Subsequently, the salinity was gradually decreased by daily dilution with freshwater, reducing five parts per day, until the target salinities of each treatment (10, 15, 20, 25, and 30‰) were reached. The algae were then maintained at these salinity conditions for the final six days of the acclimation phase.

Following acclimation, *U. ohnoi* was stocked at the density of 2 g·L<sup>-1</sup> and cultivated for 14 days. The tanks were equipped with 200 W heaters to maintain the water temperature at 28°C and provided with continuous aeration through perforated pipes to ensure adequate water movement. The algae were exposed to natural photoperiod (approximately 12 h light : 12 h dark) and ambient irradiance throughout the experiment, conducted in March. Nutrient supply was provided by the biofloc originating from a shrimp culture system. To maintain water quality and nutrient availability, 60% of the water in each tank was replaced weekly with freshly filtered biofloc water, adjusted with saltwater and/or freshwater as needed to restore the respective salinity levels of each treatment.

Seaweed was weighed once a week to monitor the increase in biomass. At the end of the experiment, the final biomass (kg) and daily growth rate were evaluated, according to Lignell & Perdesén (1989), as follows (Eq. 1):

$$\text{DGR}(\%) = [(\text{FB} / \text{IB})^{1/t} - 1] \times 100 \quad (1)$$

Where: FB: the final biomass (g); IB: the initial biomass (g); t: cultivation time.

Samples were also collected for determination of phenolic compounds, chlorophyll, and carotenoids.

## Biofloc inoculum

The characterization of the biofloc (ammonia, nitrite, alkalinity, pH, and salinity) was used as inoculum to fill the experimental units (Table 1).

**Table 1.** Water physical and chemical parameters with biofloc used as inoculum.

Ammonia (mg·L <sup>-1</sup> )	Nitrite (mg·L <sup>-1</sup> )	Alkalinity (mg·L <sup>-1</sup> )	pH	Salinity (‰)
0.13 ± 0.03	0.04 ± 0.01	154.05 ± 17.08	8.18 ± 0.16	23.9 ± 1.13

## Water quality

Dissolved oxygen, temperature, and salinity were measured daily by a digital oximeter (YSI Pro 2030) and adjusted, when necessary, with the salinity level initially determined in each treatment. Ammonia concentration (UNESCO, 1983), nitrite (N-NO<sub>2</sub>) (Strickland & Parsons, 1972), nitrate (N-NO<sub>3</sub>), orthophosphate (P-PO<sub>4</sub>), alkalinity (CaCO<sub>3</sub>) (APHA, AWWA & WEF, 2012), and pH (pH-meter Tecnal) were measured twice a week, on the inoculation day and seven days after inoculation.

## Phenolic compounds, chlorophyll and carotenoids in *Ulva ohnoi*

At the end of the experiment, samples of *U. ohnoi* were collected, frozen, and subsequently freeze-dried at -50°C and 200 µHg (Freeze-dryer L101, LIOBRAS). To determine phenolic compounds, a sample of 0.15 g of each lyophilized mass was macerated in 3.75 mL of methanol 80 % (v/v), followed by incubation for 1 hour in the dark. Then, it was centrifuged (12,000 g × 10 minutes), and finally the supernatant was collected for reading. The total content of phenolic compounds was determined using the Folin-Ciocateu colorimetric method (λ = 750 nm), according to the methodology described by Schiavon et al. (2012) with modifications. Gallic acid was used as a standard curve (Sigma-Aldrich, St. Louis, MO, USA—100–1,250 µg·mL<sup>-1</sup>, y = 0.0108x, r<sup>2</sup> = 0.999). The results were expressed in µg gallic acid equivalent per g dry weight (µg GAE·g<sup>-1</sup> DW).

Chlorophyll *a* and carotenoids were determined by macerating 100 mg of lyophilized biomass in 2 mL of methanol. After 60-min incubation at 4°C in the dark, the absorbance at 665 and 652 nm were measured to calculate the chlorophyll-*a* (Eq. 2); and at 450 nm to calculate β-carotene (Eq. 3; r<sup>2</sup> = 0.999), following the methodology by Porra et al. (1989) and Ritchie (2006).

$$\text{Chl-}a = 16.51 \times A_{665} - 8.0962 \times A_{652} \quad (2)$$

$$[\text{A}_{450} / 2.704 (\mu\text{g})] \text{ volume / weight} \quad (3)$$

## Statistical analysis

Data are presented as mean ± standard deviation (SD) and subjected to Shapiro-Wilk's and Levene's tests to prove the prerequisites of normality and homoscedasticity, respectively. Then, an analysis of variance (one-way ANOVA) was applied to verify differences among treatments, followed by the Tukey's

test when differences were found (Zar, 2010). All statistical tests were evaluated with a significance level of 5% ( $p \leq 0.05$ ) and performed using the Statistica version 13.5 program.

## RESULTS

### Water quality

Dissolved oxygen was maintained at  $7 \text{ mg}\cdot\text{L}^{-1}$ , temperature

at  $28^\circ\text{C}$ , and salinity was according to each treatment. After changing the water in the experimental units throughout the experiment, the nitrogen compounds (ammonia, nitrite, and nitrate), phosphate, and pH showed no significant differences among treatments, showing a statistical difference only for alkalinity. One day before the water exchange, nitrite, nitrate, and pH showed significant difference (Table 2).

**Table 2.** Water physical and chemical parameters on the inoculation day (ID) and seven days after inoculation (D7), during 14 days of *Ulva ohnoi* cultivation in water from a biofloc system at different salinities (10, 15, 20, 25, and 30‰)\*.

Treatment		Salinity 10‰	Salinity 15‰	Salinity 20‰	Salinity 25‰	Salinity 30‰	p-value
Ammonia ( $\text{mg}\cdot\text{L}^{-1}$ )	ID	$0.19 \pm 0.0$	$0.06 \pm 0.05$	$0.14 \pm 0.14$	$0.18 \pm 0.13$	$0.07 \pm 0.05$	0.209
	D7	$0.15 \pm 0.15$	$0.10 \pm 0.14$	$0.16 \pm 0.23$	$0.15 \pm 0.15$	$0.15 \pm 0.09$	0.889
Nitrite ( $\text{mg}\cdot\text{L}^{-1}$ )	ID	$0.02 \pm 0.0$	$0.03 \pm 0.01$	$0.03 \pm 0.01$	$0.03 \pm 0.01$	$0.08 \pm 0.11$	0.530
	D7	$0.16 \pm 0.13^a$	$0.67 \pm 0.47^b$	$0.23 \pm 0.14^a$	$0.20 \pm 0.05^a$	$0.17 \pm 0.07^a$	< 0.001
Nitrate ( $\text{mg}\cdot\text{L}^{-1}$ )	ID	$3.10 \pm 0.0$	$3.95 \pm 1.08$	$2.90 \pm 0.67$	$3.45 \pm 0.87$	$4.25 \pm 0.78$	0.160
	D7	$3.87 \pm 1.62^{ab}$	$4.08 \pm 1.43^{ab}$	$2.88 \pm 1.00^a$	$2.93 \pm 0.47^{ab}$	$2.64 \pm 0.85^a$	0.009
Phosphate ( $\text{mg}\cdot\text{L}^{-1}$ )	ID	$0.25 \pm 0.0$	$0.50 \pm 0.24$	$0.47 \pm 0.19$	$0.52 \pm 0.20$	$0.50 \pm 0.20$	0.423
	D7	$0.04 \pm 0.02$	$0.14 \pm 0.14$	$0.15 \pm 0.22$	$0.11 \pm 0.12$	$0.11 \pm 0.10$	0.797
Alkalinity ( $\text{mg}\cdot\text{L}^{-1}$ )	ID	$80.0 \pm 0.0^a$	$89.50 \pm 8.23^a$	$109.00 \pm 8.25^b$	$121.50 \pm 5.97^{bc}$	$129.00 \pm 10.52^c$	< 0.001
	D7	$93.33 \pm 2.31$	$133.17 \pm 83.56$	$110.33 \pm 36.03$	$115.33 \pm 33.47$	$139.50 \pm 12.30$	0.382
pH	ID	$8.25 \pm 0.0$	$8.20 \pm 0.06$	$8.19 \pm 0.07$	$8.19 \pm 0.06$	$8.17 \pm 0.07$	0.575
	D7	$8.16 \pm 0.07^a$	$8.40 \pm 0.22^{ab}$	$8.76 \pm 0.28^c$	$8.74 \pm 0.33^c$	$8.71 \pm 0.30^{bc}$	<0.001

\*Letters in the same line represent statistical differences according to Tukey's test ( $p \leq 0.05$ ). (mean  $\pm$  standard deviation).

### Seaweed performance

Biomass gain and daily growth rate showed a statistical difference among treatments. The 10‰ treatment exhibited total mortality in the first five days of the experiment, and treatment with salinity 15‰ showed lower values of performance than treatments with salinities 20, 25, and 30‰ (Table 3).

**Table 3.** *Ulva ohnoi* performance throughout 14 days of cultivation in water from a biofloc system at different salinities (10, 15, 20, 25, and 30‰)\*.

Treatment	Salinity 10‰	Salinity 15‰	Salinity 20‰	Salinity 25‰	Salinity 30‰	p-value
Biomass gain (g)	-	$110.53 \pm 10.26^a$	$318.46 \pm 40.28^b$	$322.04 \pm 83.90^b$	$399.53 \pm 37.76^b$	< 0.001
Daily growth rate ( $\%\cdot\text{day}^{-1}$ )	-	$1.24 \pm 0.36^a$	$5.44 \pm 0.50^b$	$5.42 \pm 1.02^b$	$6.37 \pm 0.38^b$	< 0.001

\*Letters in the same line represent statistical differences according to Tukey's test ( $p \leq 0.05$ ). (mean  $\pm$  standard deviation).

**Table 4.** Chlorophyll, carotenoids, and phenolic compounds after 14 days of cultivation in water from a biofloc system at different salinities (10, 15, 20, 25, and 30‰) (mean  $\pm$  standard deviation).

Treatment	Salinity 10‰	Salinity 15‰	Salinity 20‰	Salinity 25‰	Salinity 30‰	p-value
Chlorophyll ( $\mu\text{g}\cdot\text{g}^{-1}$ )	-	$4.27 \pm 1.28$	$5.82 \pm 1.50$	$7.88 \pm 1.42$	$5.79 \pm 1.76$	0.155
Carotenoids ( $\mu\text{g}\cdot\text{g}^{-1}$ )	-	$7.93 \pm 2.60$	$10.15 \pm 1.18$	$12.52 \pm 1.80$	$9.82 \pm 2.90$	0.218
Phenolic compounds ( $\mu\text{g}\cdot\text{g}^{-1}$ )	-	$0.37 \pm 0.06$	$0.32 \pm 0.03$	$0.34 \pm 0.04$	$0.33 \pm 0.08$	0.831



## DISCUSSION

Maintaining water quality is essential for the successful cultivation of any aquatic organism. For seaweed, minimum concentrations of dissolved oxygen, temperature, pH, nitrogen, and phosphorus are crucial for nutrient uptake and, consequently, growth. According to Imchen (2012), high concentrations of nutrients in the water are not harmful to *Ulva* species and promote a positive correlation with algal growth. Biofloc technology is characterized by continuous nutrient production. Therefore, the integration of seaweed into such systems has been explored as a strategy to control the accumulation of these compounds. In the present study, all water quality parameters remained according to the recommended ranges for *U. ohnoi* cultivation (Angell et al., 2015; Khhoi & Fotedar, 2011; Notoya, 1999).

Seaweeds constantly undergo physiological processes, and growth rate is a direct indicator of their tolerance to environmental factors (Kirst, 1990). Angell et al. (2015) reported that the optimal salinity range for *U. ohnoi* growth lies between 25 and 40‰. In this study, salinity exerted a limiting effect on the growth of *U. ohnoi*, demonstrating that this species does not tolerate low salinities (10‰), as evidenced by the rapid decline in growth rate after the first five days of exposure. In all other treatments, the seaweed survived throughout the experimental period. These results contrast with those of Silva et al. (2008), who reported moderate to high growth rates for *Cladophora coelothrix*, *Chaetomorpha indica*, and *Ulva* sp. at salinities between 10 and 20‰. However, such differences are likely species-specific and may also be influenced by exposure time and nutrient availability.

The results of this study indicated that *U. ohnoi* exhibited significantly higher growth at salinities above 20‰, suggesting an enhanced ability to uptake nutrients under these conditions. Nitrate concentrations were notably lower at salinities of 20, 25, and 30‰, corresponding to an increase in algal biomass. Conversely, at 10‰, a marked decrease in biomass was observed, accompanied by higher nutrient concentrations in the water and subsequent mortality of *U. ohnoi* thalli.

Martins et al. (2020) conducted a similar study cultivating *U. ohnoi* and *U. fasciata* using biofloc as a nutrient source and reported a growth rate of  $4.3\% \cdot \text{day}^{-1}$  at a salinity of 34‰, along with significant nutrient uptake, particularly nitrogen and orthophosphate. In the present study, higher growth rates ( $5.42\text{--}6.37\% \cdot \text{day}^{-1}$ ) were recorded at salinities of 20, 25, and 30‰ under comparable biomass density conditions. Similarly, Morais et al. (2023) reported a growth rate of  $5.43\% \cdot \text{day}^{-1}$  for *Ulva* integrated into an IMTA system with tilapia and shrimp at a salinity of 20‰. In contrast, Carvalho et al. (2023), working in an integrated system with tilapia and *U. lactuca*

at 19‰, reported a growth rate of only  $0.14\% \cdot \text{day}^{-1}$  for macroalgae cultivated near the surface, while biomass loss was observed when the algae were cultivated at the bottom of the system. In another study, Carvalho et al. (2024) evaluated different concentrations of suspended solids (100, 200, 250, and 300  $\text{mg} \cdot \text{L}^{-1}$ ) for *U. lactuca* cultivated using shrimp effluent at a salinity of 28‰ and reported specific growth rates of  $0.30\% \cdot \text{day}^{-1}$ . Rocha et al. (2023) evaluated the growth of *U. ohnoi* cultivated with biofloc effluent at a salinity of 38‰ and reported a specific growth rate of  $3\% \cdot \text{day}^{-1}$ . As noted in a previous research, such variations in growth performance are likely to reflect underlying metabolic adjustments (Fort et al., 2024), which may, in turn, influence the nutritional quality of the resulting biomass (Steinhagen et al., 2025).

The production and accumulation of natural metabolites in seaweeds of the genus *Ulva*, such as pigments, polyunsaturated fatty acids, phenolic compounds, vitamins, and polysaccharide, are influenced by environmental factors including salinity, irradiance, and nutrient availability, as well as by species-specific traits and developmental stage (Cikos et al., 2021). Pigments such as chlorophylls, carotenoids, and phycobilins play fundamental roles in photosynthesis, photoprotection, and defense mechanisms against both herbivory and oxidative stress (Cotas et al., 2020; Eismann et al., 2020; Steinhagen et al., 2025). Among these factors, salinity has been extensively studied, with documented effects on chlorophyll levels in *U. fasciata* and *U. pertusa* (Kakinuma et al., 2004, 2006).

In the present study, however, no significant differences were observed in chlorophyll concentrations at salinities above 15‰, likely due to the high nutrient availability provided by the biofloc system. Similarly, Bews et al. (2021) reported that although low salinity (15‰) negatively impacts the metabolism of *U. lactuca*, affecting growth and photosynthesis, these effects can be mitigated through sufficient nutrient enrichment.

While environmental factors modulate the biosynthesis of these compounds, algal responses can be highly variable. Steinhagen et al. (2025), for instance, found that unlike protein content and growth, pigment and phenolic compound levels did not follow a consistent pattern in response to salinity, showing considerable variation among *Ulva* species and strains.

Regarding carotenoids, the broad variation described in the literature ( $0.005\text{--}900 \text{ mg} \cdot \text{g}^{-1}$ ; Eismann et al., 2020) is consistent with environmental variation. In the present study, only beta-carotene was quantified, justifying the lower values observed compared to other studies. Legarda et al. (2021a) reported concentrations of  $16.46 \pm 3.41 \mu\text{g} \cdot \text{g}^{-1}$  in a biofloc system, comparable to the values obtained at 25‰ salinity in this study.

Antioxidant activity, mainly attributed to phenolics, plays a crucial role in protecting against auto-oxidation processes (Ramarathnam et al., 1986). Legarda et al. (2021a) reported antioxidant activity of  $0.19 \pm 0.03 \mu\text{g}\cdot\text{g}^{-1}$ , while the present study obtained higher values ( $0.32 \pm 0.03 \mu\text{g}\cdot\text{g}^{-1}$ ), indicating a possible influence of the cultivation environment.

In summary, although pigments and phenolics play essential adaptive roles, their variability between strains, species, and environmental conditions, especially salinity, reflects the complexity of biochemical regulation mechanisms in seaweed. These compounds are of increasing commercial interest, especially in the pharmaceutical, cosmetic, and functional food industries (Steinhagen et al., 2025).

## CONCLUSION

The results obtained in the present study demonstrated that at salinities of 20, 25, and 30‰ it is possible to cultivate the green seaweed *U. ohnoi* without affecting its growth and nutrient uptake. Nevertheless, this seaweed experienced complete mortality at 10‰. Considering the aim to integrate this species, it is recommended to use salinity from 20 to 30 ‰.

## CONFLICT OF INTEREST

Nothing to declare.

## DATA AVAILABILITY STATEMENT

The data will be available upon request.

## AUTHORS' CONTRIBUTION

**Conceptualization:** Morais, A.P.M., Santos, I.L., Hayashi, L., Vieira, F.B.; **Formal Analysis:** Morais, A.P.M., Santos, I.L., Hayashi, L., Lorenzo, M.A.; **Investigation:** Morais, A.P.M., Santos, I.L., Lorenzo, M.A.; **Methodology:** Morais, A.P.M., Santos, I.L.; **Writing – original draft:** Morais, A.P.M., Simioni, C.; **Writing – review & editing:** Simioni, C., Vieira, F.B.; **Funding acquisition:** Hayashi, L., Seiffert, W.Q., Vieira, F.B.; **Supervision:** Hayashi, L., Seiffert, W.Q.; **Project administration:** Seiffert, W.Q., Vieira, F.B.; **Final approval:** Vieira, F.B.

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## DECLARATION OF USE OF ARTIFICIAL INTELLIGENCE TOOLS

The authors declare that no artificial intelligence tools were used in the preparation, analysis, or writing of this manuscript.

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