Nanobubble technology: a method to increase the growth rate of Atlantic salmon (*Salmo salar*) and reduce biofouling in recirculating aquaculture system (RAS)

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Introduction

- Salmon aquaculture traditionally operated in open net pens in the ocean, but trend is moving towards land-based aquaculture in Canada[1]
- Recirculating aquaculture system (RAS) is considered to be more environmentally friendly method than open net pen due to lack of interaction with the marine ecosystem[2]
- RAS reuses water up to 99% and has complete control of growth environment[2]
- Despite the advantage, RAS requires various factors, but one primary factor is presence of dissolved oxygen (DO) in water[2]
- Cleaning and disinfecting RAS is done regularly, but requires money, labour, and energy[1,3]
- Nanobubble (NB) technology could be used to mitigate those factors
- NBs are small bubbles with diameters >1000 nm and can be stable for few months[4,5]
- About 100 million bubbles can be dissolved in a mL of water[5]
- Several theories about the stability of water, and one of them is attachment of OH^- on to its surface[5]

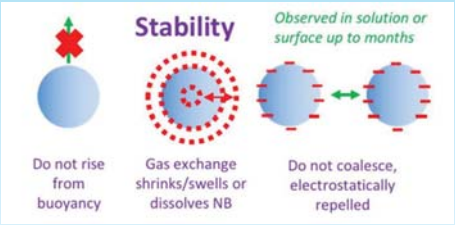

Figure 1. Diagram of stability of nanobubble (Atkinson et al., 2019, modified[5])

- Applications of NB emerging in various fields: wastewater treatment, biomedical field, and industrial field[5,8]
- Effectiveness of NB: removal or prevention of fouling particles[6,7], disinfection of water[6,8], water quality improvement[6], and fish growth[9]

Objectives

1. Can nanobubble oxygen improve the growth of fish by improving oxygen uptake efficiency?
2. Can nanobubble oxygen help reduce biofouling in RAS by improving water quality?

- **Hypothesis**: *Nanobubble oxygen will increase fish growth and reduce biofouling in RAS.*

Materials and Methods

Experimental Design

- 144 Atlantic salmon post-smolts were used
- 24 fish in each tank (n=6)
- Control (Lab #1) – ordinary oxygen (n=3)
- Test (Lab #2) – nanobubble oxygen (n=3)

Figure 2. Photos of experimental settings. Control room (top left) with oxygen injection vessel (bottom left), and test room (top right) with nanobubble generator (bottom right)

Water quality

- DO (%) and temperature (°C) collected twice daily before feeding
- Effluent water quality parameters collected: pH, ammonia (ppm), nitrite (ppm), and nitrate (ppm)

Timestamp	Name	Value	Units	Meter	Location
2024-10-24 5:52 AM	Ca	356	ppm	Spin Touch	RAS7
2024-10-24 5:52 AM	pH	7.1		Spin Touch	RAS7
2024-10-24 5:52 AM	Phosphate	0.5	ppm	Spin Touch	RAS7
2024-10-24 5:52 AM	Nitrite	0.3	ppm	Spin Touch	RAS7
2024-10-24 5:52 AM	Magnesium	1378	ppm	Spin Touch	RAS7
2024-10-24 5:52 AM	Ammonia	1.3	ppm	Spin Touch	RAS7
2024-10-24 5:52 AM	Alkalinity	118	ppm	Spin Touch	RAS7
2024-10-24 5:52 AM	Nitrate	0	ppm	Spin Touch	RAS7

Figure 3. Photos of water quality collecting method. Spindisk (left) used to get the data (right). Only pH, ammonia, nitrite, and nitrate data were collected

Fish sampling

- Fork length (mm) and wet weight (g) collection – week 0 ,week 4, and week 8
- Lab #1 – 382.2 ± 24.0 mm & 556.1 ± 109.1 g (initial)
- Lab #2 – 372.2 ± 25.3 mm & 510.5 ± 129.0 g (initial)
- Growth performance (specific growth rate, feed conversion ratio, and condition factor) were calculated

Figure 4. Images of data collection on fish fork length (mm) and wet weight (g)

Biofouling

- Weights of bio-balls in a mesh bag were measured before trial
- Bio-balls in a mesh bag were placed in water column in sumps

Statistical Analysis

- One-way ANOVA conducted on fork length (mm) and weight (g) between control and experimental at week 5.

Results

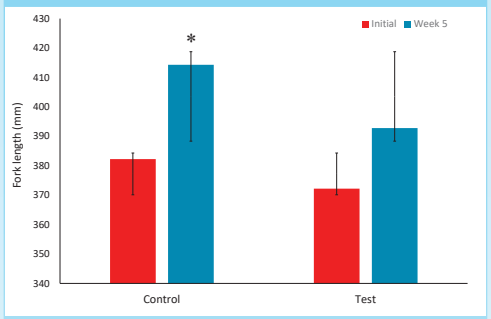

Figure 5. Comparison of fork length (mm) of salmon in control and test fish between initial and week 4. Asterisks indicate significant difference.

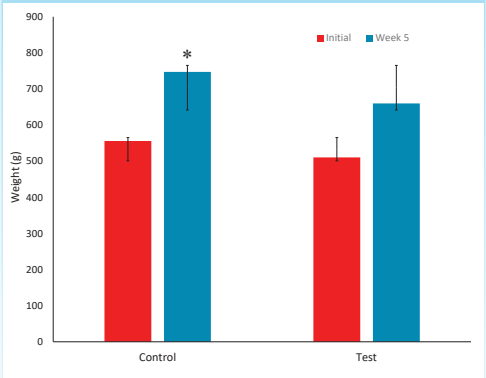

Figure 6. Comparison of weight (g) of salmon in control and test fish between initial and week 4. Asterisks indicate significant difference.

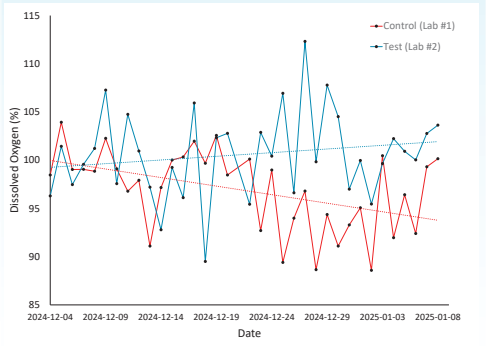

Figure 7. Dissolved oxygen (%) with trendline of lab #1 and lab #2 from Dec. 04, 2024, to Jan. 08, 2025.

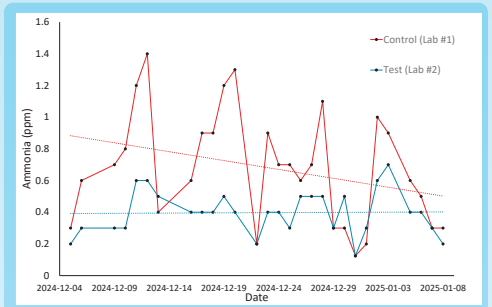

Figure 8. Ammonia (ppm) levels with trendline of lab #1 and lab #2 from Dec. 04, 2024, to Jan. 08, 2025.

ANOVA (control vs test) at week 5

- For length, results showed control and test are significantly different ($p < 0.05$) (p-value: 0.0010).
- For weight, results showed control and test are significantly different ($p < 0.05$) (p-value: 0.0169).

Weight gain

Control

- 191.2 ± 29.5 g increase from week 0 to week 5
- 34.4 % increase from week 0 to week 5

Test

- 149.4 ± 27.5 g increase from week 0 to week 5
- 29.3 % increase from week 0 to week 5

Specific Growth Rate (%/day)

- *Control*: 0.82 ± 0.21
- *Test*: 0.73 ± 0.14

Discussion

- All data from halfway point of the trial (week 5)
- Final dataset collected on January 29th.
- One-way ANOVA results indicate fish in the control system had a higher length and weight than fish in the NB system.
- However, with another 4 weeks remaining in the experiment, these results may change.
- NB treatment showed higher DO concentration than control treatment, which was expected from property of NB and was observed from Ebina et al. (2013)[9].
- NB treatment showed lower levels of ammonia than control treatment, which was expected from property of NB and was observed from Xiang and Xu (2020)[10].
- Salmon in NB treatment is expected to have higher growth rate than those in control treatment as expected from Ebina et al. (2013)[9], however, the present results at 5 weeks suggest this may not be the case in this study.

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References