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Reducing nitrogen and phosphorus discharges from sea cucumber-based recirculating aquaculture through dietary binder addition

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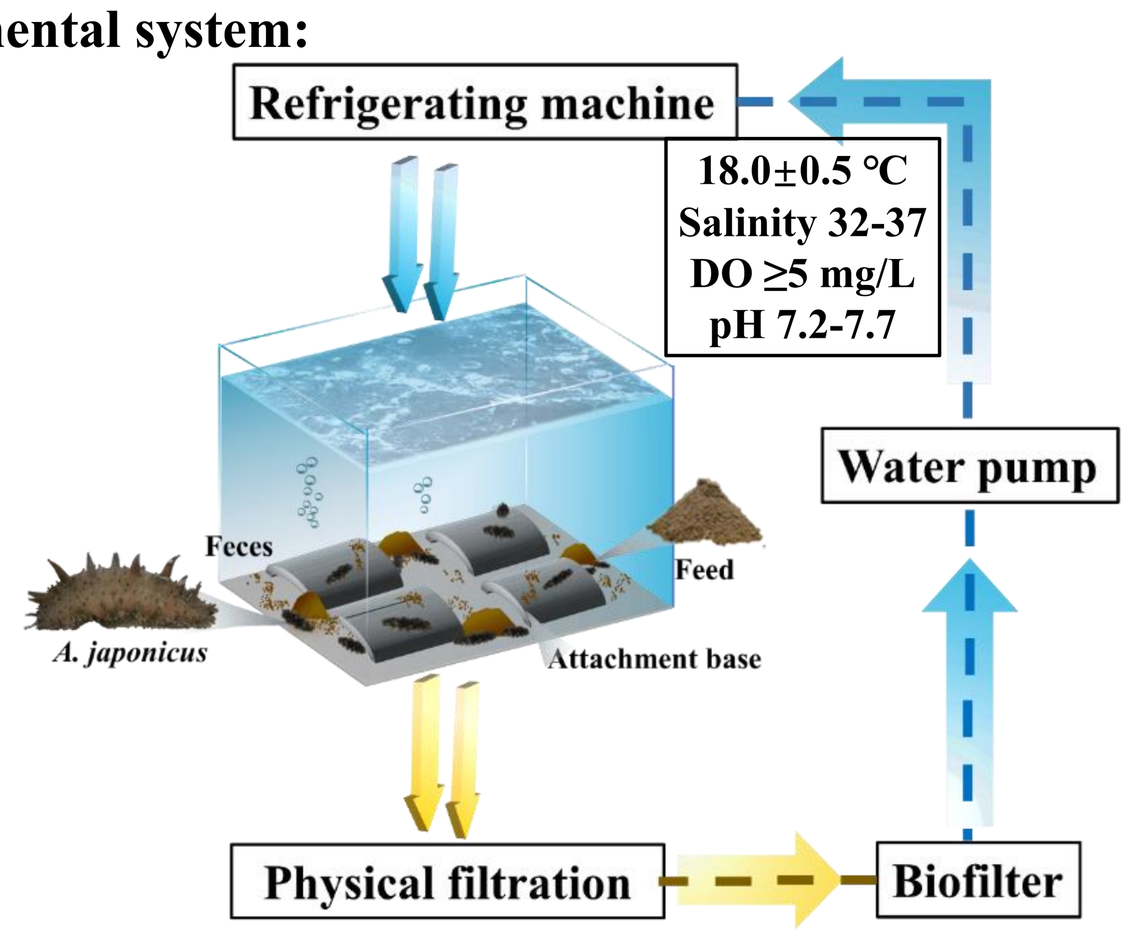
Introduction

- *Apostichopus japonicus* production in China reached 292,000 tons in 2023, a year-on-year increase of 17.52%. However, the rapid growth of the industry has raised concerns about nitrogen (N) and phosphorus (P) pollution.
- Recirculating aquaculture system (RAS) has benefits like land use reduction, water conservation and productivity. But many problems about the application of *A. japonicus* RAS need to be solved, such as dietary losses and high particulate matter in sewage waters.
- The supplementation of binders can enhance dietary stability and alter the physical properties of diet and feces, and has emerged as a promising solution to mitigate these challenges.
- The N & P budgets could quantify the sources and flows of N & P elements in RAS based on the principle of material conservation, which could comprehensively reflect the diet nutrient supply, *A. japonicus* utilization and water pollution content.
- Furthermore, This work demonstrates the feasibility of mitigating water quality management pressures through optimized dietary interventions, providing critical insights for advancing sustainable *A. japonicus* RAS practices.

Methods

- **Animal and experimental diets:** The weight of *A. japonicus* were 20.0 ± 5.0 g. The control group (Con) without binder and groups with 5% sweet potato starch (SPS), xanthan gum (XG), guar gum (GG), and carrageenan (CG), respectively.
- **Experimental design:** The experimental period lasted for 42 days. The *A. japonicus* were stocked in density 6kg/m³. Feeding occurred at 8:00am each day, with a daily feeding rate set at 5% of biomass**.**
- **Experimental system:**



- The N and P budget were calculated as follows:

$$F_{N/P} + W_{N/P} = O_{N/P} + G_{N/P} + D_{N/P} + L_{N/P}$$

Where $F_{N/P}$ is N or P input from diet, g. $W_{N/P}$ is N or P input from water, g. $O_{N/P}$ is N or P in residual bait and feces, g. $G_{N/P}$ is N or P of *A. japonicus* growth, g. $D_{N/P}$ is N or P dissolved in water, g. $L_{N/P}$ is N or P unaccounted for, g.

Conclusion

- As a dietary binder, guar gum reduced N and P concentrations in aquaculture water, with TN and TP decreased by 24.8% and 28.5%, respectively.
- The binders altered the N/P forms at sediment-water interfaces, exerting an influence on residual bait manure N/P and concomitantly reducing dissolved N/P generation in the *A. japonicus* RAS.
- Sweet potato starch and guar gum modified dietary/fecal properties, retaining more N/P in solid forms for utilization by *A. japonicus.*

Result

- **Water quality**

The binder additives were found to enhance water quality in the RAS by decreasing the concentration of NH_4^+-N and TN effectively.

- **N&P budgets**

N and P output in all groups was mostly from O_N and O_P, followed by G_N and G_P. The addition of sweet potato starch and guar gum in diet significantly increased G_N and G_P , while D_N and D_P were lower.

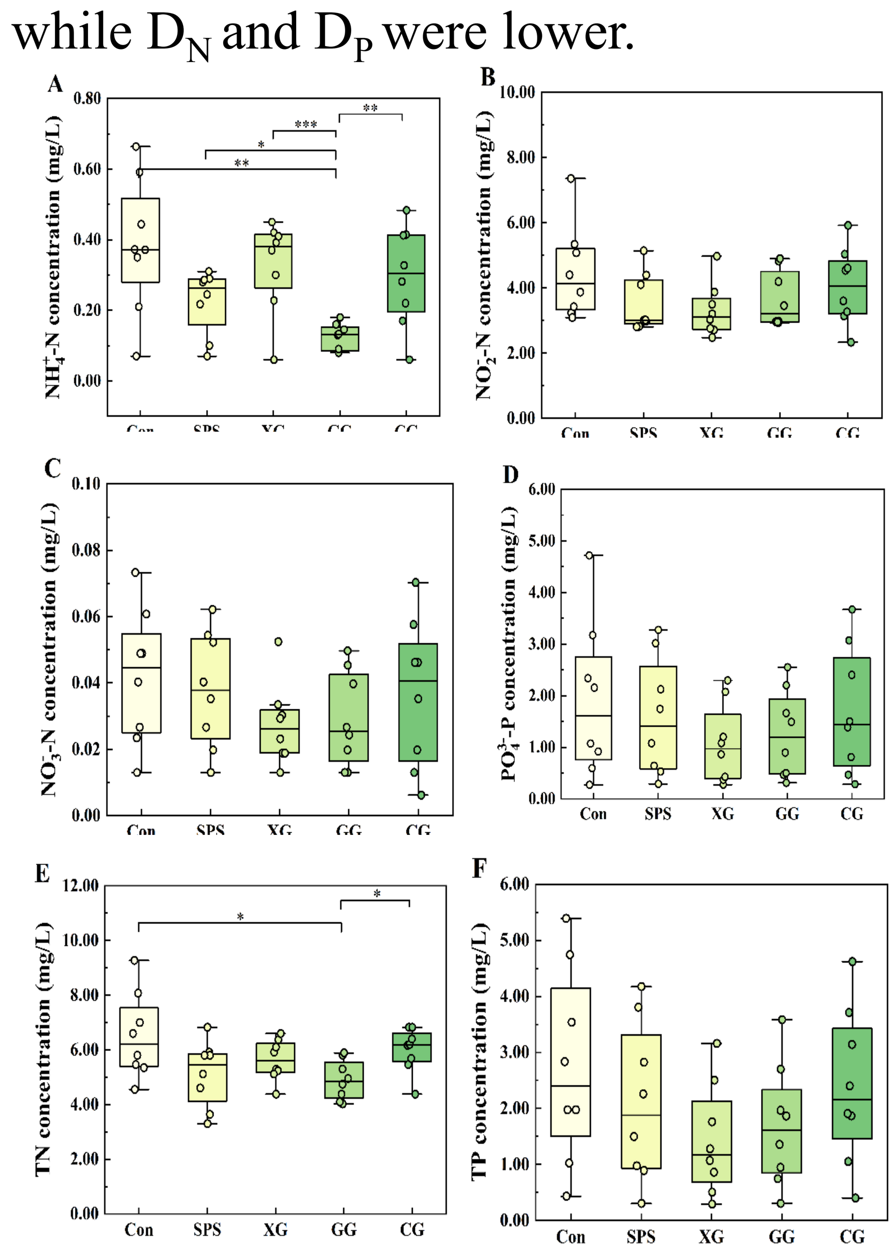


Fig. 1 Water quality at the outlet of breeding tank.

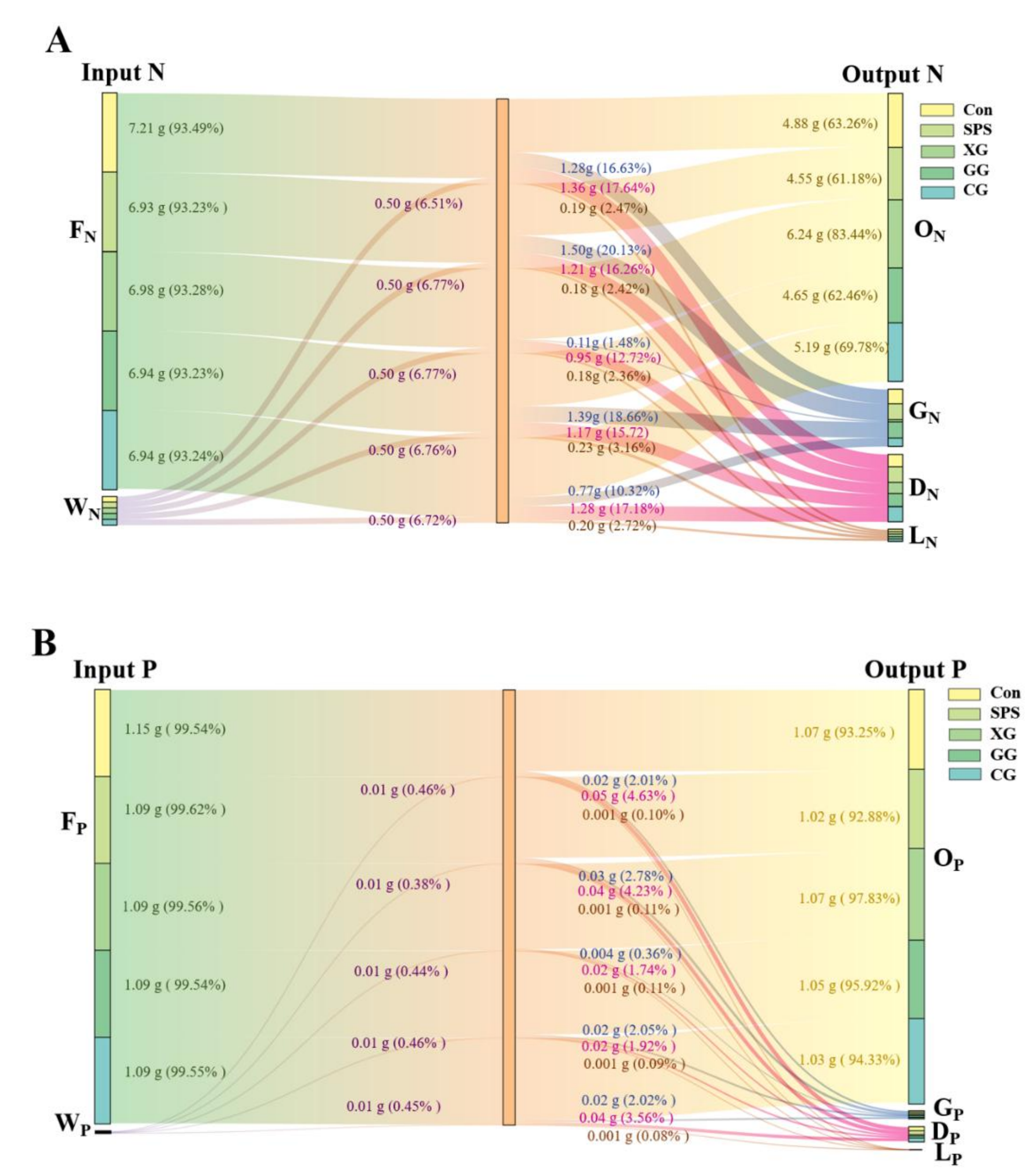


Fig. 2 (A) N and (B) P budgets in *A. japonicus* RAS.

- **Dietary & Fecal properties**

The addition of binders resulted in a substantial augmentation of the mean and fecal viscosity of *A. japonicus*. The viscosities of the feed and feces in the xanthan gum group were relatively high, being 1620±100 mPa·s and 5000±100 mPa·s respectively.

The addition of binders significantly increased dietary and fecal Dx(50) in all the experimental groups, with the largest Dx(50) and viscosity observed in group XG and the smallest in group Con.

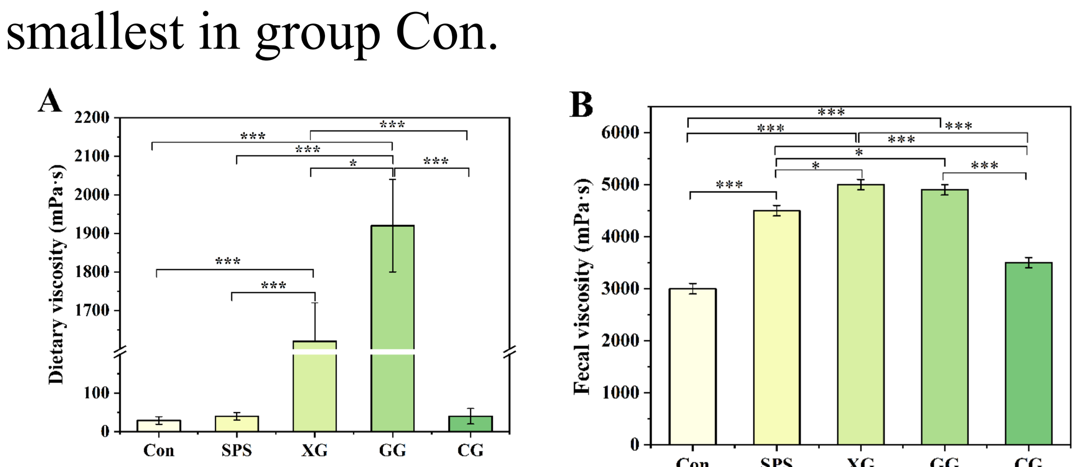


Fig. 3 (A) Dietary and (B) fecal viscosity of *A. japonicus*

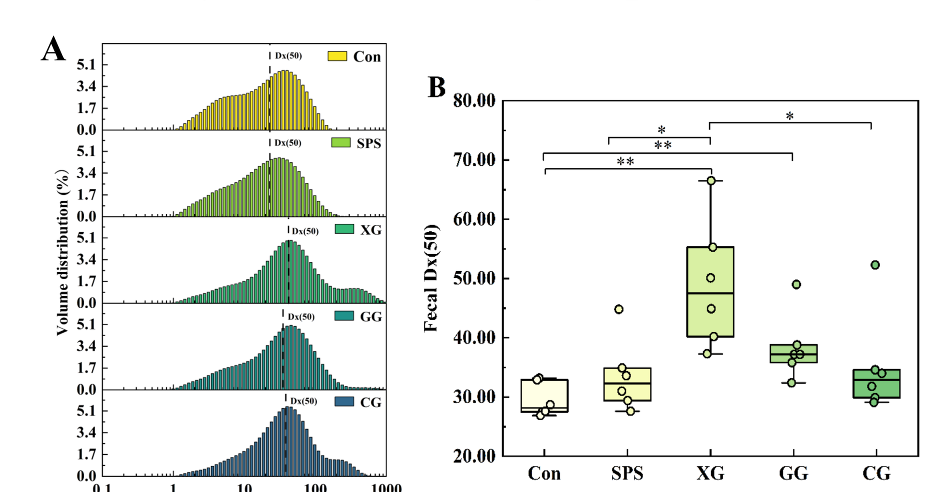


Fig. 4 (A) Dietary and (B) fecal Dx(50) distribution

- **Correlation between fecal properties and N-P budget**

In this research, no significant correlations were found between dietary Dx(50) or viscosity and G_N or G_P. Fecal Dx(50) demonstrated strongly negative correlations with D_N and D_P, while dietary viscosity showed significant negative correlations with D_N and D_P. The ExpDec3 model showed a strong fit for the relationship between Dx(50) and D_N. The Boltzmann model was well-fitted for the relationship between Dx(50) and D_P.

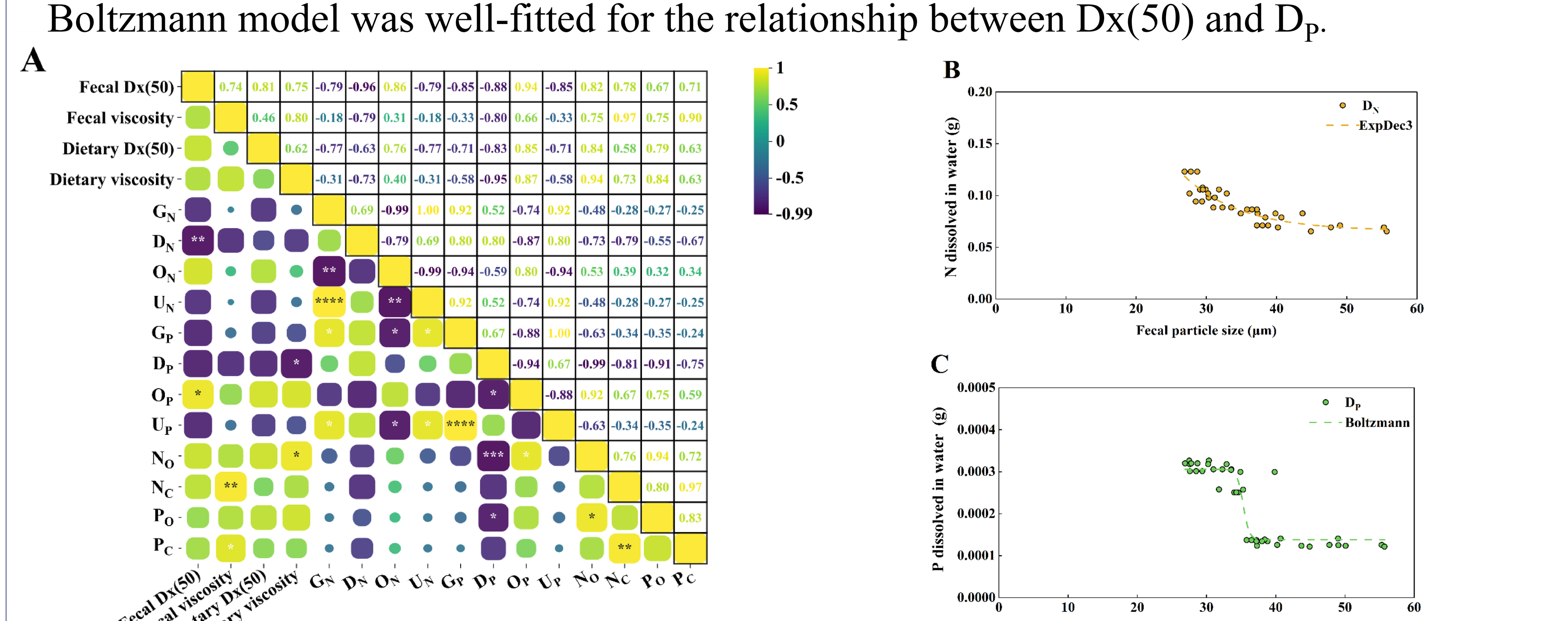


Fig. 4 (A) Correlation analysis between the dietary/fecal viscosity and N&P budgets. Relationship between (B) D_N and (C) D_P and Dx (50) of *A. japonicus* feces