Effects of dietary probiotics on growth, gonadal development and quality, antioxidant capacity, intestinal health and non-specific immunity of sea urchin (*Strongylocentrotus intermedius*)

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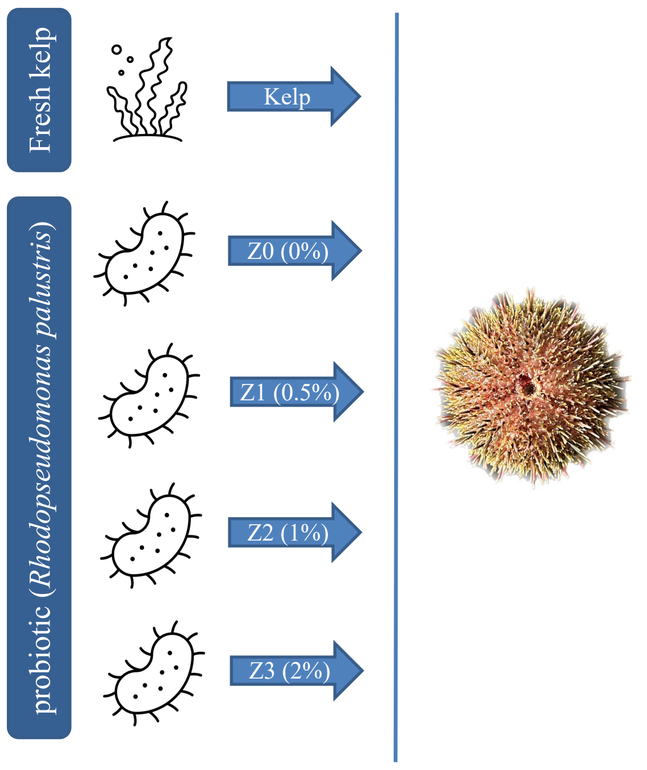
Background

Strongylocentrotus intermedius is a sea urchin whose gonads are prized worldwide for their delicious taste and high nutritional value. In the natural environment and traditional culture mode, sea urchins are primarily fed macroalgae (*Laminaria japonica* and *Undaria pinnatifida*). However, due to significant seasonal fluctuations in macroalgae supply, China experiences a shortage of kelp feed from August to November each year. Although dried and salted kelp can serve as temporary substitutes during the vacant season of fresh kelp, the drying and salting processes will increase the costs, coupled with the propensity of dried and salted kelp products to spoilage and deterioration during the high-temperature season. This condition greatly hinders the swift advancement of the sea urchin aquaculture industry. To address these issues, probiotics, which are rich in nutrients and bioactive substances, are widely used in aquaculture. This study aims to develop a new, nutrient-rich probiotic (*Rhodopseudomonas palustris*) formulated feed to overcome food shortages and nutritional deficiencies.

Methods



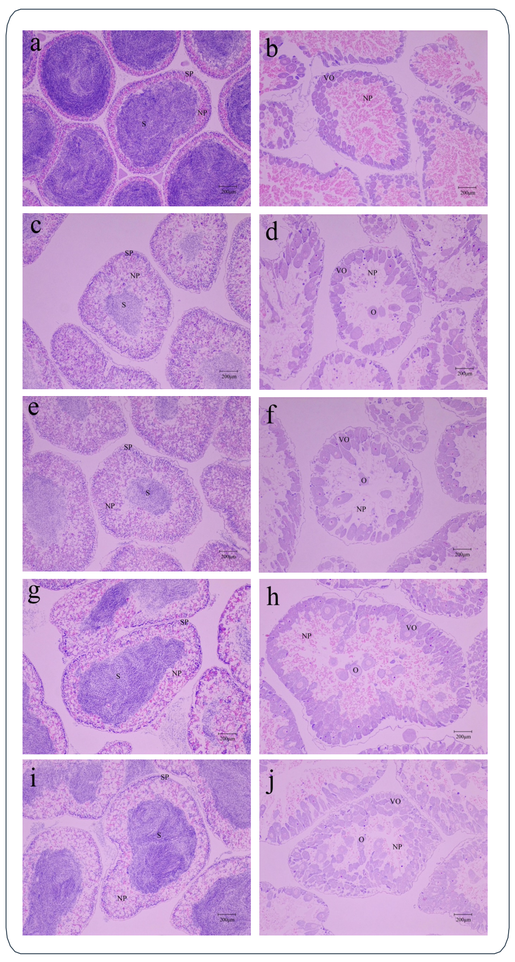
In the experiment, *S. intermedius* (initial body weight: 26.5 ± 0.17 g) were fed five different diets for 60 days: fresh kelp (*Laminaria japonica*) and four prepared feeds, Z0, Z1, Z2, and Z3 (with 0, 0.5, 1, and 2% *R. palustris*, respectively).

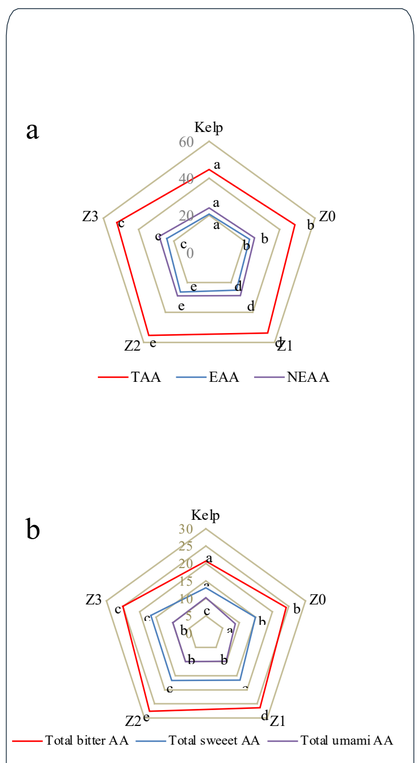
Results

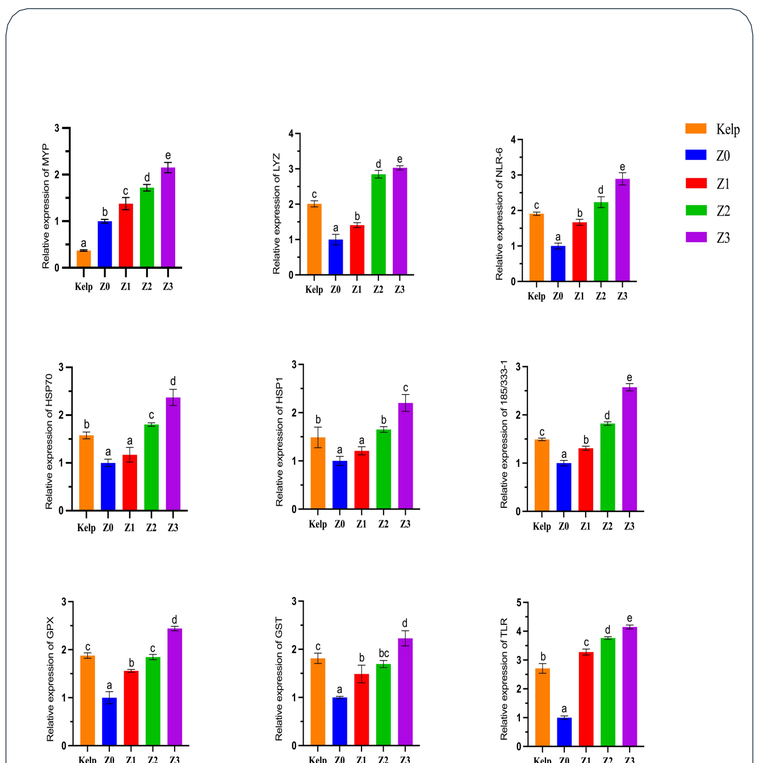
Indices	Kelp	Formulated feed groups			
		Z0	Z1	Z2	Z3
SR (%)[1]	100±0.00[a]	100±0.00[a]	100±0.00[a]	100±0.00[a]	100±0.00[a]
IBW (g)[2]	26.44±0.06[a]	26.47±0.05[a]	26.58±0.17[a]	26.36±0.26[a]	26.63±0.16[a]
FBW (g)[3]	31.42±0.29[a]	35.17±0.05[b]	36.81±0.03[c]	37.97±0.16[d]	38.06±0.34[d]
WGR (%)[4]	18.85±0.95[a]	32.85±0.26[b]	38.45±0.76[c]	44.06±0.88[d]	42.93±2.16[d]
SGR (%/d)[5]	0.29±0.02[a]	0.47±0.01[b]	0.54±0.01[c]	0.61±0.01[d]	0.59±0.03[d]
GWW (g)[6]	4.31±0.08[a]	9.18±0.07[b]	10.96±0.46[c]	11.79±0.29[d]	11.88±0.16[d]
GI (%)[7]	13.71±0.32[a]	26.10±0.23[b]	29.79±1.26[c]	31.04±0.80[cd]	31.21±0.34[d]
DTW (g)[8]	1.01±0.05[a]	1.11±0.05[a]	1.28±0.08[b]	1.36±0.03[b]	1.38±0.07[b]
DTI (%)[9]	3.22±0.19[a]	3.17±0.13[ab]	3.49±0.22[bc]	3.58±0.10[c]	3.62±0.16[c]
FI (%)[10]	18.38±1.79[b]	1.37±0.04[a]	1.27±0.03[a]	1.16±0.06[a]	1.21±0.07[a]

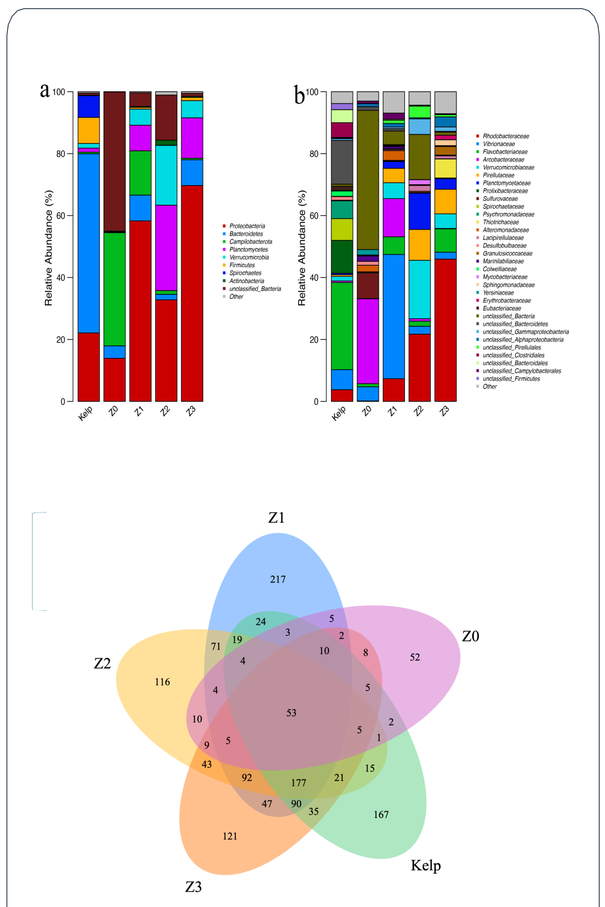
Parameter	Kelp	Formulated feed groups			
		Z0	Z1	Z2	Z3
T-AOC (U/mL)[1]	4.15±0.07[b]	3.17±0.14[a]	4.11±0.14[b]	4.69±0.12[c]	4.65±0.31[c]
SOD (U/mL)[2]	42.70±0.22[a]	44.21±0.22[b]	62.11±1.74[c]	101.69±0.22[e]	78.77±0.22[d]
CAT (U/mL)[3]	4.01±0.31[bc]	2.67±0.12[a]	3.99±0.31[bc]	4.43±0.30[c]	3.22±0.77[ab]
MDA (nmol/mL)[4]	0.43±0.04[c]	0.30±0.08[ab]	0.28±0.04[ab]	0.25±0.04[a]	0.38±0.08[bc]
GSH-S (U/mL)[5]	9.09±0.30[b]	7.58±0.61[a]	10.00±0.30[c]	11.11±0.46[d]	9.39±0.52[bc]
GSH-PX (U/mL)[6]	11.02±1.22[b]	8.16±0.70[a]	10.61±0.70[b]	11.43±1.87[b]	11.02±1.22[b]
ACP (U/100ml)[7]	2.28±0.08[a]	1.82±0.49[a]	1.92±0.05[a]	2.93±0.33[b]	2.09±0.25[a]
AKP (U/100ml)[8]	2.16±0.05[c]	1.79±0.05[a]	1.98±0.08[b]	2.84±0.11[e]	2.30±0.08[d]
LZM (U/mL)[9]	3.61±0.39[a]	4.30±0.16[a]	6.16±0.69[b]	10.93±0.36[c]	10.80±0.27[c]

Results









Results demonstrated that the addition of *R. palustris* significantly improved *S. intermedius* growth performance, antioxidant enzyme activity, immune enzyme activity, and digestive enzyme activity, while also enhancing the expression of genes related to gonadal development, immunity, and antioxidant function. The study further observed that *S. intermedius* in the 1% and 2% *R. palustris* groups showed significantly better gonad development (females), adhesiveness, chewiness, total amino acids (TAA), essential amino acids (EAA), and non-essential amino acids (NEAA) content compared to the kelp group, although their gonad color was slightly inferior. Additionally, the addition of *R. palustris* enriched the microbial diversity in the *S. intermedius* intestine, with a significant increase in the abundance of Rhodobacteraceae in the Z2 and Z3 groups compared to the other groups ($P < 0.05$), indicating a positive effect on intestine health. Overall, supplementation with 1% *R. palustris* to the diet can significantly improve the growth performance, gonadal development and quality, antioxidant capacity, intestine health, and non-specific immunity of *S. intermedius*. This study provides a potential solution to the seasonal shortage of macroalgae food in sea urchin aquaculture.

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