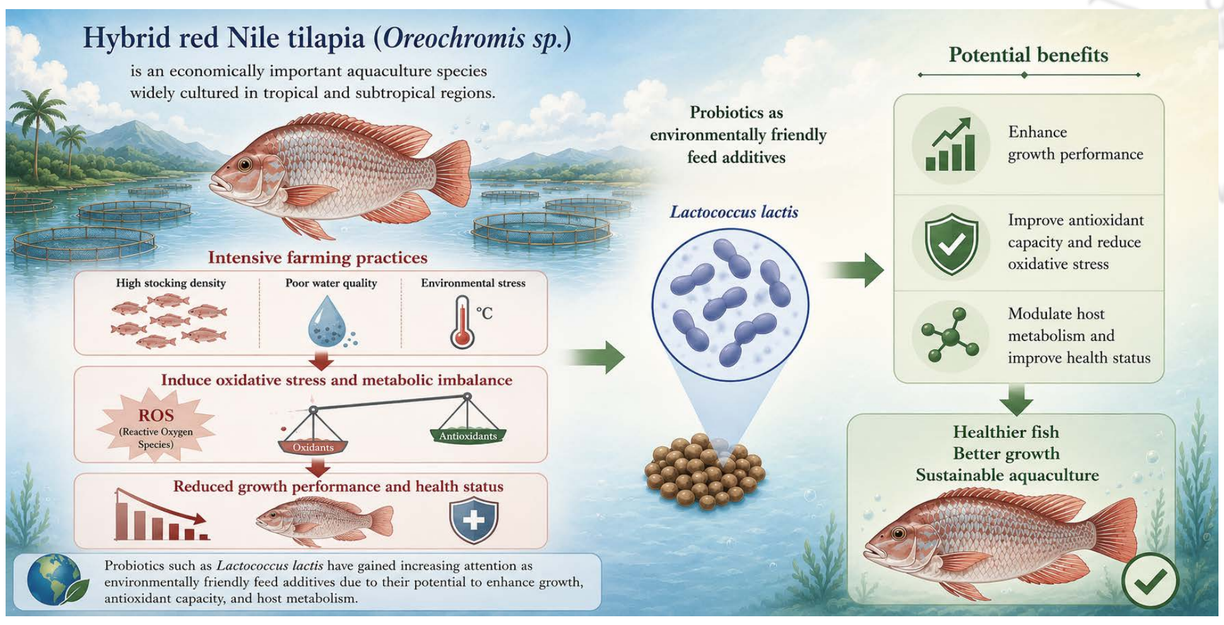
ENHANCEMENT OF GROWTH AND REDOX HOMEOSTASIS IN HYBRID NILETILAPIA BY DIETARY *Lactococcus lactis* : INSIGHTS FROM SERUM METABOLOMICS

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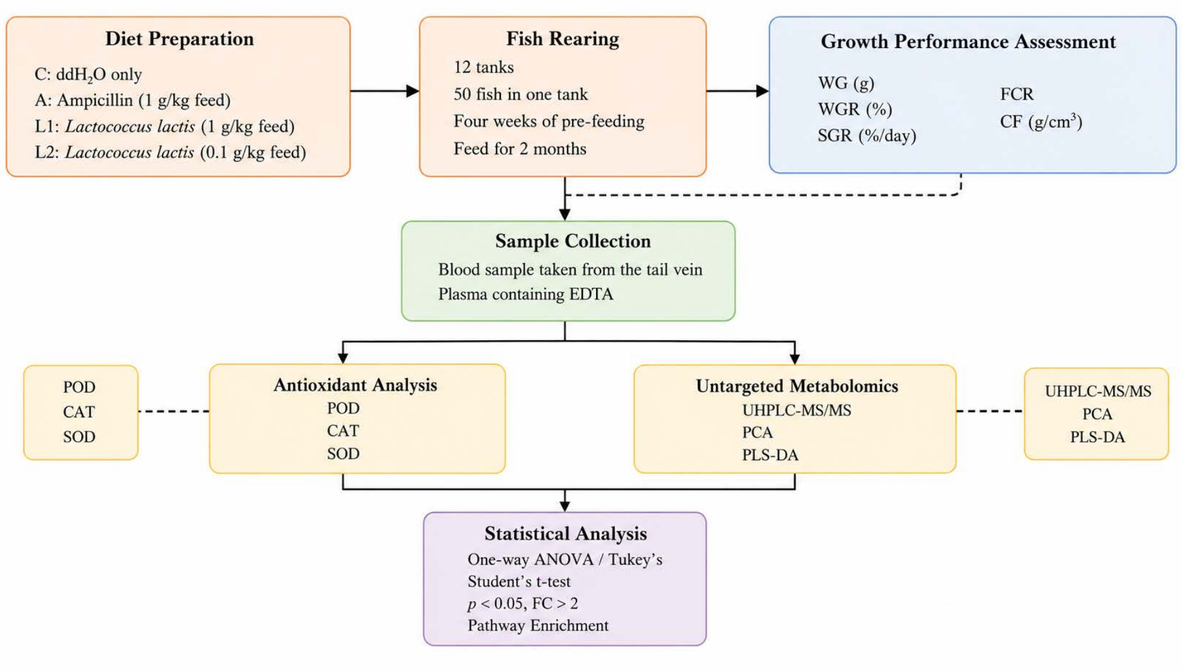
Background



Abstract

- This study investigated the effects of dietary *Lactococcus lactis* supplementation on growth performance, antioxidant capacity, and serum metabolomic profiles in hybrid red Nile tilapia (*Oreochromis* sp.).
- Results showed that probiotic-fed fish exhibited improved growth performance, with the 1.0 g/kg group (L1) showing the highest weight gain and lowest feed conversion ratio (FCR = 0.61).
- Antioxidant analysis revealed decreased SOD activity accompanied by elevated CAT and POD activities, suggesting improved redox homeostasis following probiotic supplementation.
- Untargeted serum metabolomics identified 2,612 metabolic features and indicated that arginine and carnitine metabolism pathways may be involved in growth regulation.

Experimental workflow



Result

Table 1. Growth performance of hybrid red Nile tilapia (*Oreochromis* sp.) under dietary *Lactococcus lactis* supplementation. C, control; A, antibiotic; L1, *Lactococcus lactis* 1.0 g/kg ; L2, *Lactococcus lactis* 0.1 g/kg. Boxes highlight values showing notable differences among.

Growth parameter	C	A	L1	L2
IBL	5.29	5.11	5.69	5.71
FBL	8.30	8.61	12.59	11.78
IBW	3.23	3.24	4.43	4.35
FBW	10.23	11.17	36.76	30.05
WG	7.00	7.93	32.33	25.70
WGR (%)	2.17	2.45	7.30	5.90
DWG (g day^{-1})	0.028	0.031	0.094	0.076
CF	1.789	1.750	1.842	1.838
LGR (%)	56.9	68.49	121.27	106.30
FCR	1.64	1.49	0.61	0.62
SGR (% day^{-1})	0.014	0.016	0.027	0.025
FI	558	558	897	768.5

Table 2. Antioxidant enzyme activities of hybrid red Nile tilapia under dietary *Lactococcus lactis* supplementation. C, control; A, antibiotic; L1, *Lactococcus lactis* 1.0 g/kg ; L2, *Lactococcus lactis* 0.1 g/kg. POD, peroxidase; CAT, catalase; SOD, superoxide dismutase.

Antioxidant enzyme	C	A	L1	L2
POD	240.1	1225.0	431.2	793.8
CAT	11.50	16.90	15.43	14.94
SOD	5.34	9.10	0.90	1.36

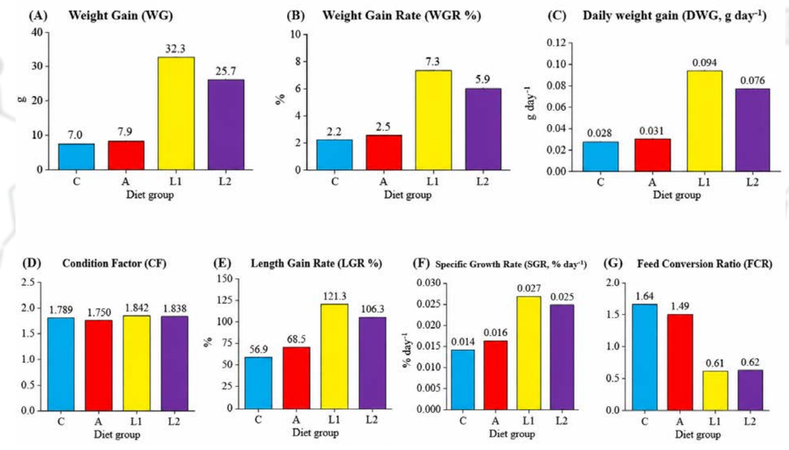


Fig.1. Dietary *Lactococcus lactis* supplementation improves growth performance in hybrid red Nile tilapia.Fish were fed a control diet(C), an antibiotic diet (A), or *Lactococcus lactis*–supplemented diets (L1; L2), and growth-related parameters (A–G) were measured at the end of the feeding trial (means, n = 3).

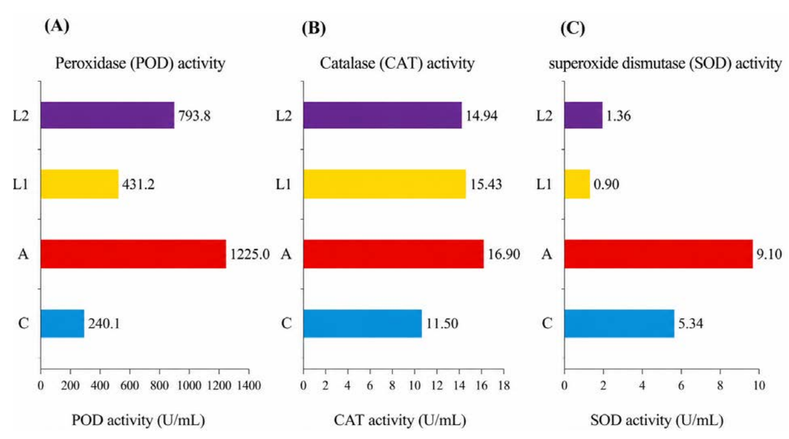


Fig.2. Dietary *Lactococcus lactis* supplementation modulates serum antioxidant enzyme activities in hybrid red Nile tilapia. Fish were fed control (C), antibiotic (A), or *Lactococcus lactis*–supplemented diets (L1; L2), and serum (A) peroxidase (POD), (B) catalase (CAT), and (C) superoxide dismutase (SOD) activities were measured at the end of the feeding trial (U/mL; means, n = 3).

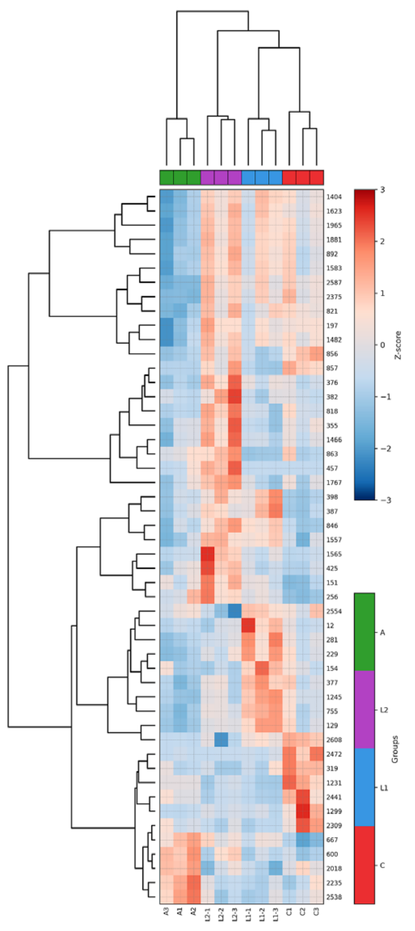


Fig.3.Antibiotic and probiotic treatments induce distinct alterations in serum metabolite signatures in hybrid red Nile tilapia. Z-score–normalized metabolomic profiles were subjected to hierarchical clustering, demonstrating clear separation among Control (C), Antibiotic (A), high-dose (L1), and low-dose (L2) dietary groups. These results indicate that dietary interventions markedly modulate systemic metabolic responses in tilapia.

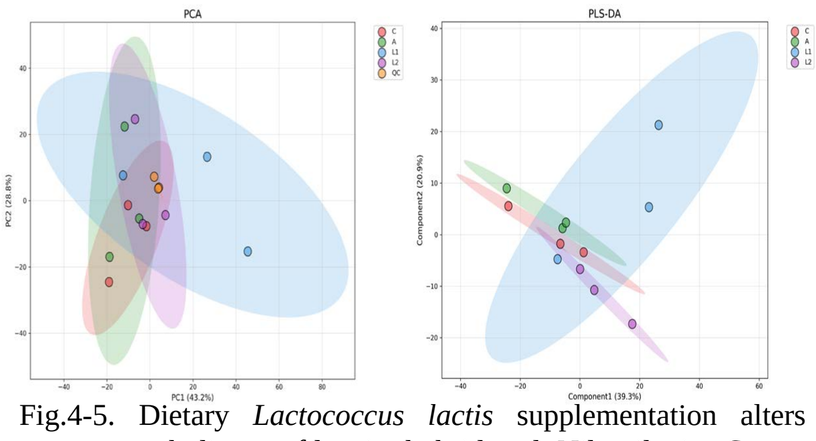


Fig.4-5. Dietary *Lactococcus lactis* supplementation alters serum metabolite profiles in hybrid red Nile tilapia. Serum metabolomics data were analyzed using PCA (Figure 4) and PLS-DA (Figure 5) to compare metabolic differences among C, A, L1, and L2 groups. Each point represents one biological replicate (n = 3), and shaded ellipses indicate 95% confidence regions.

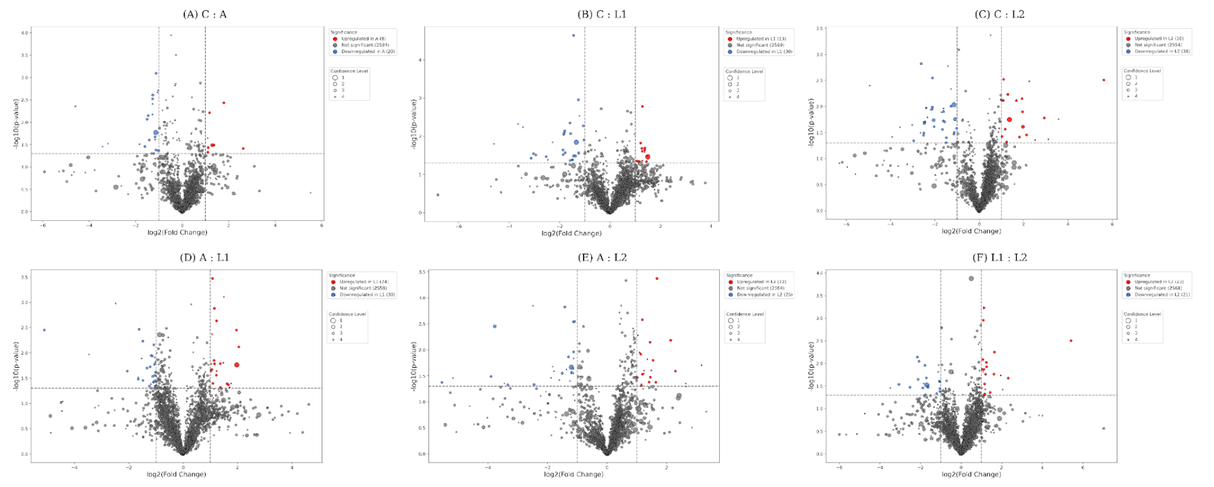


Fig.6. Antibiotic and probiotic treatments induce distinct alterations in plasma metabolite signatures in hybrid red Nile tilapia. Volcano plot analysis of pairwise dietary group comparisons reveals treatment-specific metabolic responses.

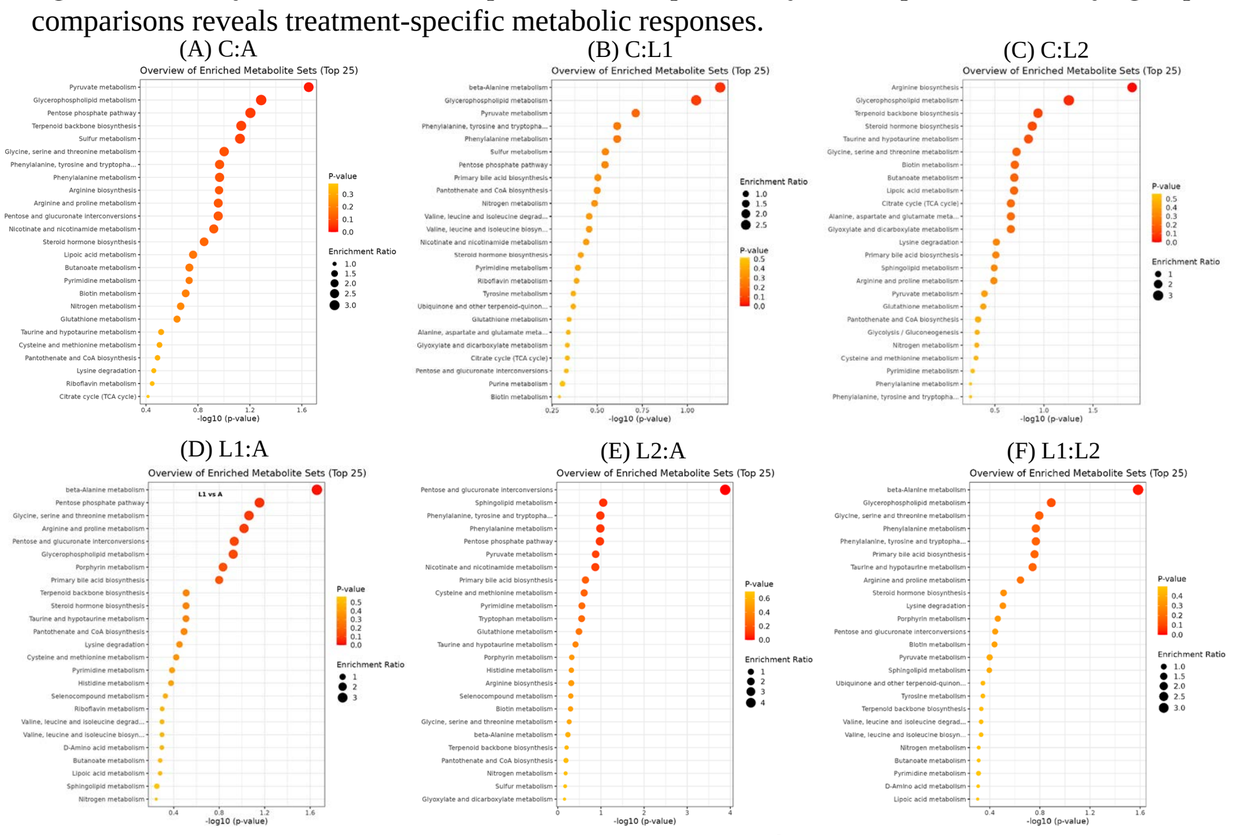


Fig.7. Antibiotic and probiotic treatments alter enrichment of key metabolic pathways in hybrid red Nile tilapia. Metabolite set enrichment analysis highlights treatment-specific modulation of central carbon and amino acid metabolism across dietary groups.

Conclusions

- Growth Performance: Dietary *Lactococcus lactis* supplementation significantly improved growth efficiency, with L1 and L2 groups showing markedly higher weight gain and lower FCR values compared with the control group.
- Physiological Homeostasis: Probiotic supplementation reduced oxidative stress, as indicated by decreased SOD activity, while maintaining improved physiological stability relative to the control and antibiotic groups.
- Metabolic Changes: Serum metabolomic analysis revealed alterations in arginine and carnitine metabolism pathways, suggesting enhanced energy mobilization and growth regulation.
- Application Potential: Although L1 showed the strongest biological response, the L2 group achieved comparable feed efficiency with lower supplementation cost, indicating better economic potential.