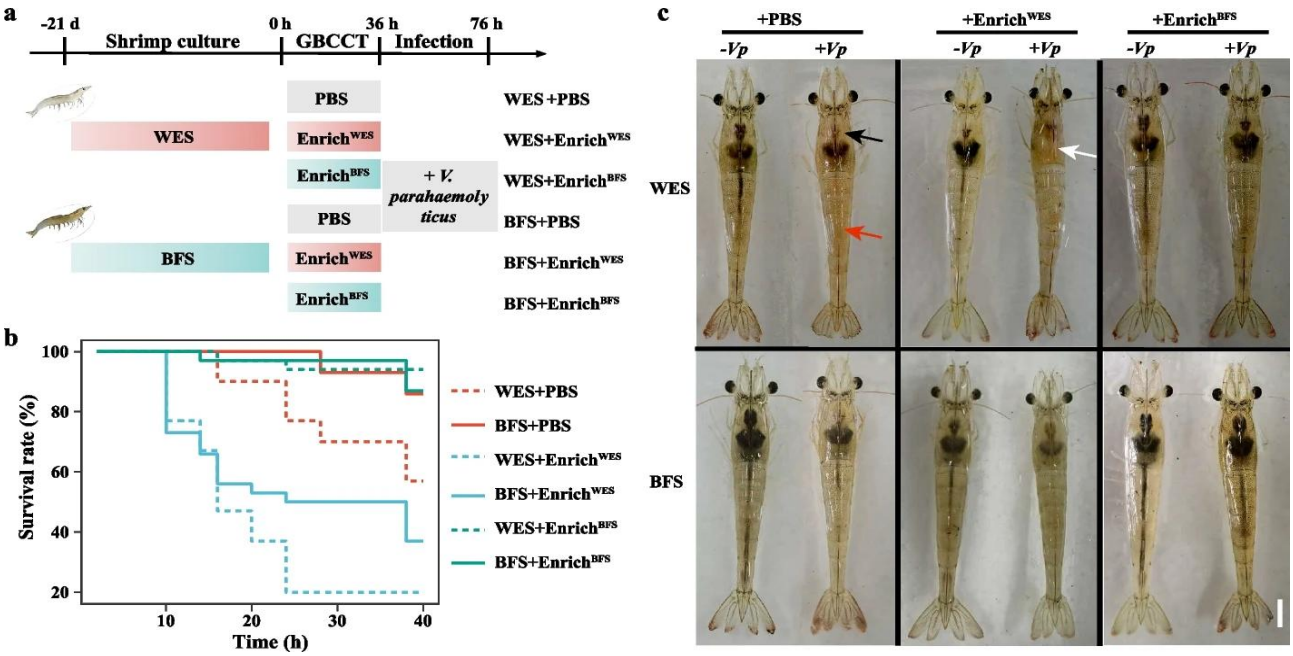

Figure 3 The Vibrio infection resistance, and phenotypic characteristics of shrimp after cross-transplantation of bacterial consortia enriched from WES and BFS shrimp (Adopted from Guo et al., 2023)

Image caption: (a) Schematic diagram of the experimental procedure. The bacterial consortia were obtained from the shrimp cultured in the WES and BFS for 21 days, and the bacterial consortia were cross-transplanted to WES and BFS shrimp. After 36h of cross-transplantation, the shrimp that received PBS and bacterial consortia were infected by the pathogenic Vibrio parahaemolyticus. (b) The effects of cross-transplantation on the shrimp survival curves after infection; c Phenotypic characteristics of shrimp after infection. Black, white, and red arrows indicate the stomach, hepatopancreas, and gut of shrimp in (c), respectively. Bar=1 cm in (c); WES, Water exchange system; BFS, Biofloc system; PBS, Phosphatic buffer solution; EnrichWES, Bacterial consortium obtained from WES shrimp; EnrichBFS, Bacterial consortium obtained from BFS shrimp; -Vp, non-Vibrio infection; + Vp, Vibrio infection (Adopted from Guo et al., 2023)

5.3 Immunoregulation and genetic breeding

Due to the absence of a typical adaptive immune system in shrimp, conventional vaccination strategies are limited in their ability to provide long-term protection. Therefore, enhancing innate immunity and improving host resistance through genetic approaches have become key strategies for long-term disease control. Immunoregulation techniques aim to enhance host resistance through immune priming and functional additives. Common immunostimulants include polysaccharides derived from plants, algae, and microorganisms, as well as vitamins and minerals. These compounds can activate pattern recognition receptors, regulate signaling pathways such as NF-κB, and upregulate antimicrobial peptide expression, thereby improving resistance to WSSV and Vibrio infections.

In recent years, the concept of "trained immunity" has gained increasing attention in shrimp health management. Studies suggest that early stimulation or nutritional interventions can induce an enhanced innate immune state, thereby improving resistance to subsequent infections. Furthermore, broodstock nutrition and epigenetic regulation may influence offspring resistance, providing new perspectives for disease prevention (Wikumpriya et al., 2023). Mechanisms such as DNA methylation, histone modification, and non-coding RNA regulation are believed to play roles in immune gene expression and transgenerational resistance (Wikumpriya et al., 2023).

In terms of genetic breeding, the development of disease-resistant strains offers a long-term and stable solution for disease control. Traditional selective breeding has already achieved progress in certain cultured populations. With advances in molecular technologies, approaches such as marker-assisted selection (MAS), genomic selection, and genome-wide association studies (GWAS) are increasingly applied to elucidate disease resistance traits. Studies indicate that resistance to WSSV in Litopenaeus vannamei exhibits relatively high heritability, demonstrating the