Effect of Organic acid and Cellulose on Stress response and Water stability of feed for Pacific White Shrimp (*Litopenaeus Vannamei*) at High Temperatures

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Abstract

High water temperature conditions (>30 ℃) impose significant physiological stress on Pacific white shrimp (*Litopenaeus vannamei*) and accelerate the deterioration of feeds in static-water aquaculture systems, leading to reduced feed efficiency and environmental deterioration. This study evaluated the effects of a mixed organic acid (OA) complex and high-concentration cellulose (HCC) on shrimp growth performance, feed stability, and economic feasibility under thermal stress conditions. A 90-day feeding trial was conducted at a commercial shrimp farm in Gunsan, Republic of Korea. A total of 400,000 juvenile shrimp (initial weight 10.0 ± 0.2 g) were randomly distributed into four ponds (100,000 shrimp per pond) with two replicates per treatment. Two diets were tested: a commercial control diet (45% crude protein, 6% crude lipid) and an experimental extruded pellet diet (45% crude protein, 7% crude lipid) supplemented with 0.4% OA and 0.1% HCC. The experimental diet was formulated using fish meal (37.9%), squid liver powder (13%), and soybean meal (9.8%) as the primary protein sources, with 2% fish oil and 18% cereals/starch as energy and binding sources. Pellet size was adjusted from 1.2 to 1.5 mm according to shrimp growth stages, and shrimp were fed to apparent satiation three times daily.

Shrimp fed the experimental diet showed significantly improved performance compared with those fed the control diet, with higher survival (88.5% vs. 81.0%) and weight gain (37.5 vs. 33.0 g/ shrimp), while feed consumption was reduced (44.1 vs. 49.4 g/ shrimp), indicating improved feed utilization efficiency ($P < 0.05$). In addition, diets containing 0.1% HCC exhibited superior pellet integrity during a 48-hour immersion test and significantly reduced crude protein and crude lipid leaching.

Through a two-stage formulation optimization process, the inclusion level of HCC was reduced from 0.5% to 0.1% without compromising pellet stability, lowering the additive cost to approximately 0.003 USD/ kg of feed. These results demonstrate that the synergistic application of mixed organic acids and optimized HCC provides a practical and cost-effective strategy for improving feed stability, enhancing shrimp growth performance, and supporting sustainable intensive aquaculture of *L. vannamei* under high-temperature farming conditions.

1. Background and purpose

- The Pacific white shrimp (*Litopenaeus vannamei*) remains a cornerstone of the global aquaculture industry, including in South Korea, due to its immense commercial value.
- Water temperature is a critical determinant of growth and survival for this species, with optimal performance typically observed within a range of 27–30℃ (Wyban et al., 1995; Chen et al., 2020).
- However, during the summer months in South Korea, water temperatures often exceed this optimal range, leading to abiotic stress that compromises physiological development and intestinal microbiota homeostasis. These conditions are further exacerbated by pathological threats, most notably *Vibrio*-induced bacterial infections (Akbary & Aminikhoei, 2018).
- In typical south korean static-water systems, these thermal challenges are further compounded by the accelerated disintegration of feed pellets, triggering water quality deterioration and subsequent production losses.
- Therefore, this study aimed to evaluate the synergistic effects of mixed organic acids (OA) and high-concentration cellulose (HCC) on improving feed stability and growth performance under these stressful thermal conditions.

2. Materials and Methods

1st Experimental condition- Jeollabuk-do-Gunsan

- **Stocking density**: 400,000 juvenile shrimp (initial weight of 10 ± 0.2g) were randomly distributed into 4 ponds, 100,000 shrimp per pond) with two replicates per treatment.
- Pond specifications: Each pond had a total area of 1,250m^2, resulting in a stocking density of 80 individuals/m$^{2.}$
- **Aeration & water movement**: To ensure optimal dissolved oxygen and water circulation, four paddlewheel aerators were installed in each pond and operated continuously.
- **Water temperature**: 28.0± 3.0℃; Mean ± SD), maintained throughout the 90-day trial.

Preparation of the 1st experimental diets

- The experimental diets was prepared. (Table 1).
- **Experimental design**: Two diets were prepared: a commercial control diet (45% CP, 6% CL) and an experimental diet (45% CP, 7% CL) specifically formulated to test the synergistic effects of functional additives.
- **Primary protein sources**: The experimental diet included fish meal (37.9%; combined grades), squid liver powder (13.0%), and soybean meal (13.5%) as the main protein components.
- **Energy and lipid sources**: Wheat flour (18.0%) and tapioca starch (2.5%) were used as carbohydrate sources, while fish oil (2.0%) and soy lecithin (1.5%) served as the primary lipid sources.
- **Functional additives**: A dietary 0.4% OA complex (7:3 blend of Calcium Propionate and Calcium Butyrate) and 0.1% HCC were supplemented to improve physiological resilience and pellet water stability.
- **Pellet manufacturing**: Experimental diets were produced as extruded pellets (EP), with sizes adjusted from 1.2 mm to 1.5 mm to accommodate the different growth stages of the shrimp.
- All experimental diets were assigned to duplicate groups of fish.
- Shrimp were fed to apparent satiation three times a day (09:00, 13:00, 17:00).
- **Water Stability Test:** To evaluate pellet water stability, the leaching rates of experimental diets supplemented with either 0.1% HCC (Highly Concentrated Cellulose) or 0.5% standard cellulose were measured at 0, 12, 24, and 48 hours post-immersion in seawater.

3. Results

The greatest weight gain (37.5 g) and survival (88.5%) were observed in shrimp fed the experimental diet (**Fig. 1**).

FCR of shrimp fed the experimental diet was significantly ($P < 0.05$) lower than that of the Con diet (**FIg1**).

Feed consumption of shrimp fed the diet was significantly ($P < 0.05$) lower than shrimp fed Con diet **(Fig 1).**

Water Stability of Pellet: Experimental diets with 0.1% HCC showed superior integrity (Fig. 2), with significantly higher retention of crude protein (99.8%) and crude lipid (97.8%) after 48 h (Fig. 2).Economic Feasibility: Optimization of HCC to 0.1% successfully minimized additive costs to 0.003 USD/kg while maintaining performance.



Table 1. Ingredient and chemical composition of the experimental diets (%, DM basis).

Control diets		Experimental diets (Daehan feed)
Commercial Control diets	Ingredient (%)	
	Fish meal (FM)	25.9
	Tuna by-product meal	12.0
	Poultry by product	4.0
	Squid liver powder	13.0
	High Concentrate Celluose	0.1
	Organic acid	0.4
	Soybean meal	13.5
	Wheat flour	18.0
	Strach	2.5
	Fish oil	2.0
	Soy lecithin	1.5
	Others	7.1
	Nutrients (%, DM)	
7.6%	Dry matter	7.9%
45.1%	Crude protein	45.0%
6.0%	Crude lipid	7.0%
11.6%	Ash	12.7%
12.4%	Estimated energy(kJ/g)	12.8%

Fig 1. Survival (%), weight gain (g/shrimp), specific growth rate (SGR, %/day) and feed consumption of shrimp fed the experimental diets for 90 days

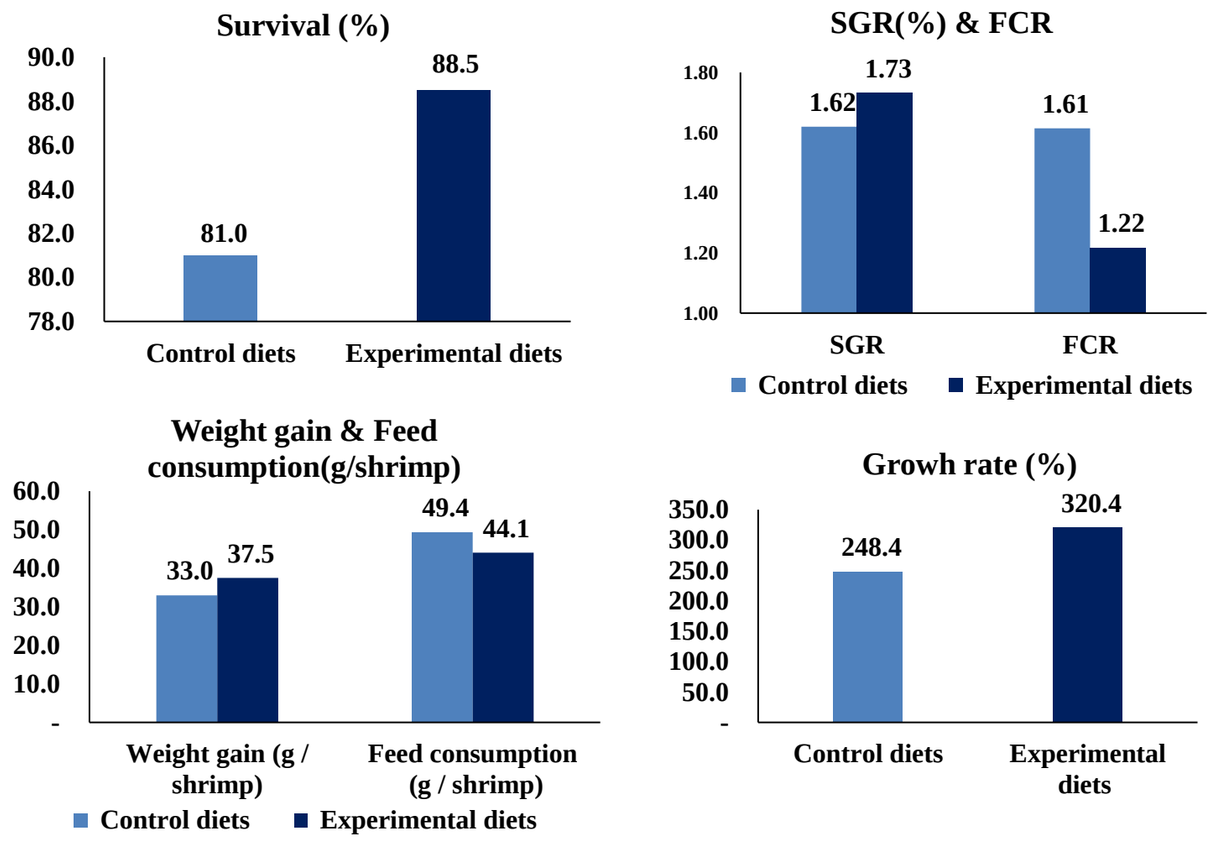
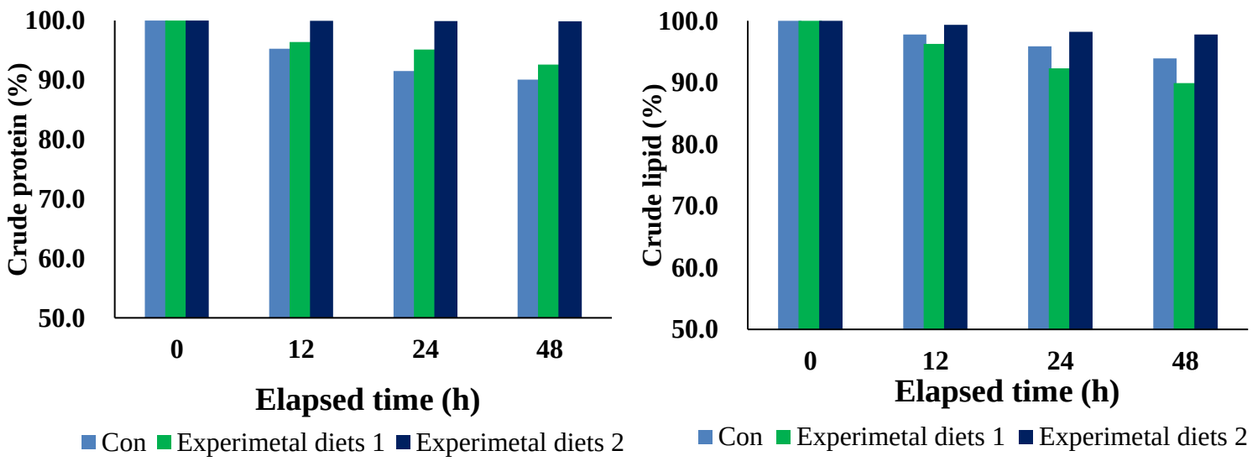


Fig 2. Changes in crude protein and crud lipid content (%) of the experimental diets following immersion in seawater for 12, 24, and 48 h (means of triplicate ± SE; ANOVA with repeated design: times [$p < 0.0001$] and the interaction of experimental diets and immersion time [$p < 0.0001$]). Different letters in each time point indicate significant ($p < 0.05$) differences between the experimental diets within each time point..



4. Conclusion

The dietary supplementation of 0.1% highly concentrated cellulose and an organic acid complex significantly enhanced the water stability of extruded pellets, effectively minimizing nutrient leaching. These improvements subsequently led to optimized FCR and maximized growth performance, demonstrating a cost-effective formulation strategy for shrimp aquaculture.

