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Research Article

Influence of Varying Salinity and Different Protein Sources on the Water Quality Changes During the Rearing of Pacific White Shrimp, *Litopenaeus vannamei* (Boone, 1931)

P Pravallika[1]*, D Ravindrakumar Reddy[2], A Chnadrashekar Rao[3], Prasanna Kumar[4] and Shyam Prasad Mamidala[5]

[1]*PG Student, College of Fishery Science, SVVU, Muthukur, AP, India*

[2]*Professor and University Head, Department of Aquaculture, College of Fishery Science, SVVU, Muthukur, AP, India*

[3]*Assistant Professor, College of Fishery Science, SVVU, Muthukur, AP, India*

[4]*Professor, Department of Live Stock Management, PVNRTVU, TS, India*

[5]*Assistant Professor, College of Fishery Science, PVNRTVU, TS, India*

***Corresponding Author:** P Pravallika, PG Student, College of Fishery Science, SVVU, Muthukur, AP, India.

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Abstract

A study was conducted for 63 days to study the influence of varying salinity (0, 10, 15, 25 ppt) and different protein sources on the water quality changes during the rearing of Pacific white leg shrimp, *Litopenaeus vannamei*. The shrimp diet was prepared at three protein level (25%, 30% and 35%) by mixing all the ingredients in required proportions into pellets by the replacement of fish meal with Cottonseed meal, (CSM), sunflower meal (SF), *Acetes indicus* (AI) meal, Mysid meal (MM). Shrimps were fed with the diets thrice a daily at a satiation level. Water quality parameters such as pH, temperature, dissolved oxygen (DO), total alkalinity and total hardness was analysed weekly intervals. In the study, the water pH ranged between 8.2 to 8.3, 8.2 to 8.3, 8.3 to 8.4 and 8.4 to 8.5 for 0, 5, 15, and 25 ppt, respectively. While the temperature and dissolved oxygen ranged between 29.5 to 31.7°C and 5.66 and 7.81 mg l^{-1}, respectively in all the treatments. Moreover, the total alkalinity varied between 214 to 155 mg l^{-1}, 315 to 229 mg l^{-1} and 625 to 535 mg l^{-1} and 725 to 645 mg l^{-1} at 0, 5, 15 and 25 ppt, respectively. Similarly, the total hardness of water ranged between 238 to 191 mg l^{-1}, 322 to 240 mg l^{-1}, 675 to 601mg l^{-1} and 777 to 700 mg l^{-1} at 0, 10 15 and 25 ppt, respectively irrespective of varying protein sources in the diets. In conclusion, the study revealed the feasibility of *L. vannamei* up to 25 ppt salinity as the water quality parameters are within the suitable ranges irrespective of varying dietary protein sources and growth.

Keywords: Water Quality; *Litopenaeus vannamei;* Salinity; Pacific White Shrimp

Introduction

Global consumption of shrimp and fish has been increasing steadily during the past decade as a result of economic growth and expansion of aquaculture production. Shrimp is one of the most promising aquaculture commodities, which are expected to continue to increase in coming years all over the world including India. In parallel to this, Pacific white shrimp, *Litopenaeus vannamei* has become a game challenger in Indian shrimp aquaculture in recent years [1]. The farming of this exotic species has registered incredible thrust in India due to its faster growth rate, tolerance to high stocking density, lower dietary protein requirement and tolerance to wide range of salinity and temperature [2]. Moreover, the availability of specific pathogen resistant (SPR) and specific pathogen-free (SPF) seed of this species has made it a species of choice for profitable aquaculture in recent years.

In India, the intensification of farming systems especially the shrimp aquaculture sector has created questions about the mainte-

nance of optimal nutrients in the culture system as well as impact of practices on the surrounding environment [3,4]. Since most of the potential areas for shrimp farming have already explored in India, additional production can only be achieved through successful manipulation and maintenance of various environmental factors that directly or indirectly influence the productivity of culture system. In general, management of any culture system is mainly based on fertilization strategies, coupled with good quality soil and water quality management [3]. Aquatic animals are in equilibrium with potential disease organisms and their environment. Changes in equilibrium such as deterioration in water quality can result in stress and vulnerable to diseases to aquatic animals. Therefore, it is very much important to maintenance of optimum water quality parameters and their maintenance for the better production of aquatic animals especially in shrimp farming, where water quality is a major concern. Salinity is an important parameter to control growth, survival and osmoregulation in shrimps [3]. *L. vannamei* may have the ability to survive in a wide range of salinities, but its growth can vary significantly among different salinity conditions. Considering the importance of water quality under varying salinity and protein diet fed, the present study was undertaken to determine the optimum as well as interactive effect of selected water quality parameters on the rearing of *L. vannamei* under the influence of varying salinities and protein sources.

Material and Methods

Shrimp and rearing conditions

The experiment was conducted for 63-days in the Wet Laboratory rearing facilities, Department of Aquaculture, College of Fishery Science, Sri Venkateswara Veterinary University, Muthukur, India. A total of 1500 numbers of *L. vannamei* seed were procured from the CP Hatchery and reared in farmer's pond till it reaches an approximate weight of 2.5g for 25 days at 30 ppt salinity. Then the seed was acclimatized to the required salinities i.e., 0 ppt, 5 ppt, 15 ppt and 25 ppt by slowly adding fresh water at the rate of reduction of 2 ppt salinity per hour.

The aquarium tanks used for experiments were of size 60x30x40 cm. Eighty-one aquariums were stalked on iron racks. Aquariums were located in a secured place where there is no direct sunlight and covered all the sides with black paper to avoid algal growth in the tank. Water in the aquariums was aerated by using air stones connected to the air compressor. Biological filters are prepared and used for filtering the aquarium water. The saline water was taken into a tank and allowed to aerate for 48 hours and was used for filling the aquaria. The water is allowed to filter for 24 hours before introducing the shrimps into the aquaria. Ten numbers of Shrimps with initial average weights of 2.5 were introduced into each aquarium and triplicates were maintained for each treatment such as Fish Meal 25 (FM25), Fish Meal 30(FM30), Fish Meal 35 (FM35), Cotton Seed Meal 25 (CSM25), Cotton Seed Meal 30 (CSM30), Cotton Seed Meal 35 (CSM35) *Acetes indicus* 25(AI 25), *Acetes indicus* 30 (AI 30), *Acetes indicus* 35 (AI 35), Sunflower meal 25(SF 25), Sunflower meal 30(SF 30), Sunflower meal 35(SF35), Mysid meal 25(MM 25), Mysid meal 30 (MM 30), Mysid meal 35(MM 35), at four different salinities of 0 ppt,5 ppt, 15 ppt and 25 ppt. The shrimp diet was prepared at three protein levels (25%, 30% and 35%) by mixing all the ingredients in required proportions, ground and sieved to the required size and made into pellets. Diet was prepared by replacement of fish meal with Cottonseed meal, (CSM), sunflower meal (SF), *Acetes indicus* (AI) meal, Mysid meal (MM). Shrimps were fed with the diets thrice a daily at a satiation level. Water exchange of up to 50% was done in each tank at regular intervals daily. Left overfeed, excreta, and other debris were siphoned off from the bottom of the tank without disturbing the shrimps.

Water quality indices

The following water quality parameters are studied weekly intervals throughout the study period following the standard water quality procedure as described by APHA (2005). The water quality parameters like water temperature, dissolved oxygen (DO) and water Ph, total alkalinity (mg l^{-1}), and total hardness (mg l^{-1}) were measured in laboratory following standard methods.

- **Water Temperature (°C):** Water temperature was measured on spot using a mercury thermometer having 0.5°C accuracy.
- **pH:** The pH of water samples was measured using a digital pH meter periodically.
- **Dissolved Oxygen (mg l^{-1}):** For the estimation of dissolved oxygen content of water, the samples were collected with all necessary precautions. Winkler's method was followed for estimation of dissolved oxygen of all the treatments (APHA, 2005).
- **Alkalinity (mg l^{-1}):** Alkalinity was estimated following the titration method (APHA, 2005). 50 ml of sample was taken in a conical flask, to it 2-3 drops of phenolphthalein indicator was added. When the sample became pink, it was titrated with 0.02 N sulphuric acids until the pink color just disappeared. The quantity of acid used was recorded. Then 2-3 drops of methyl orange indicator were added and titrated against 0.02 N sulphuric acids. The endpoint was orange to wine red. The volume of sulphuric acid used was recorded and alkalinity was determined.

- **Hardness (mg l^{-1}):** Hardness is the measure of the total concentration of divalent cations such as calcium, magnesium, ferrous and strontium and is expressed in mg l^{-1}. It was estimated following the standard titration method [5]. For testing hardness, 50 ml of the sample water was taken in a conical flask. To it 1.5 ml ammonia buffer and 3 drops of Erichrome Black-T indicator were added. Then it was titrated against standard EDTA solution until the sample water color changed from wine red to blue. The volume of the EDTA solution used was recorded, and hardness was determined.

Statistical analysis

The water quality data obtained were statistically analyzed by applying Randomized Block Design (RBD) of two-way classification using excels sheet 2010 version.

Results and Discussion

The environmental factors exert a vast influence on the maintenance of a well aquatic ecosystem and production of aquatic food organisms [4]. The pH of pond water is influenced by many factors, including pH of source water, the acidity of bottom soil and shrimp culture inputs and biological activity [6]. The periodical changes in the water pH and temperature of *L. vannamei* reared in varying salinities and protein sources are present in tables 1 and 2, respectively. In the present study, water pH did not show fluctuation among the treatments. The study recorded water pH ranged between 8.2 to 8.3, 8.2 to 8.3, 8.3 to 8.4 and 8.4 to 8.5 for 0, 5, 15, and 25 ppt, respectively. However, the water pH registered significantly higher level at higher salinity treatments (i.e. 25 ppt) and was lower in lower salinity treatments (i.e. 0 ppt) irrespective of the dietary protein content. Moreover, several studies have been recommended the favorable ph range of 7.9-9.1 for the rearing of *L. vannamei* [6-8], which is in accordance with the finding of the present study. Temperature is the key factor affecting growth, production and water quality of aquatic animals as well as the system [9,10]. Water temperature is probably the most important environmental variable in shrimp culture because it directly affects metabolism, oxygen consumption, growth, molting and survival [8]. In the study, the lowest temperature was recorded at 0, 5, 15 ppt during the initial day and 14 days of rearing, whereas the highest temperature was recorded at 25 ppt during the 63 days of rearing, irrespective of the dietary protein content fed. Overall, the present study recorded a temperature range of 29.5 to 31.7°C in all the treatments. According to Ponce-palafox *et al.*, [11] and Nunes (2001), the optimum temperature for *L. vannamei* is ranged between 28.5-32.1°C, which is in conformity with the present study. The higher temperature at 25 ppt treatment is associated higher salinity level of this treatment irrespective of varying protein diet fed. This is possibly due to presence of more ions in higher salinity treatments, which increases the water temperature in the present study. According to Boyd [12], the concentration of dissolved oxygen is the variable that most influences the well being of aquatic organisms. Dissolved oxygen plays an important role in growth and production through its direct effect on feed consumption, maturation and affecting the solubility and availability of many nutrients [3,13]. Low-level of oxygen tension hampers metabolic performances in shrimp and can reduce growth and moulting and cause mortality (Jiang *et al.,* 2000). The DO level in the present study was ranged between 5.66 and 7.81 mg l^{-1} in all the treatments (Figure 1). According to Nunes (2001), the water DO for ideal shrimp farming should not be less than 5 mg l^{-1}, which is in support of the present findings. A similar DO was also reported by Aragon and Garcia [14] for shrimp farming. The total alkalinity and total hardness refer the total amount of bases and metal ions in water, respectively. This plays an important role in the maintenance of buffer water against wide fluctuation in pH of the culture system [3]. However, alkalinity and hardness are not much affected by biological and or aquacultural operations, and the initial concentrations in ponds are determined by their levels in the water supply, any changes are largely the result of rainfall and evaporation. In the present study, the total alkalinity varied between 214 to 155 mg l^{-1}, 315 to 229 mg l^{-1} and 625 to 535 mg l^{-1} and 725 to 645 mg l^{-1} at 0, 5, 15 and 25 ppt, respectively (Figure 2). Similarly, the total hardness of water ranged between 238 to 191 mg l^{-1}, 322 to 240 mg l^{-1}, 675 to 601mg l^{-1} and 777 to 700 mg l^{-1} at 0, 10 15 and 25 ppt, respectively (Figure 3). However, higher salinity groups had recorded significantly higher alkalinity and hardness values regardless of varying protein sources fed. This might be due to the presence of both titrable and metal ions primarily calcium, magnesium, bicarbonates and carbonates in the higher salinity groups (i.e. 25 ppt) than the lower salinity treatments [3]. Despite such variations, water quality parameters in all the treatments, irrespective of varying protein sources, were within the safe range as prescribed for rearing of *L. vannamei* [1,15,16].

Culture days	Salinities (ppt)	FM			CSM			AI			SF			MM		
		FM 25	FM 30	FM 35	CSM 25	CSM 30	CSM 35	AI 25	AI 30	AI 35	SF 25	SF 30	SF 35	MM 25	MM 30	MM 35
7	0	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
	5	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.2	8.3	8.3	8.3	8.3	8.3	8.3
	15	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.3	8.4	8.4
	25	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
14	0	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
	5	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
	15	8.3	8.3	8.3	8.4	8.4	8.4	8.4	8.3	8.4	8.4	8.4	8.4	8.4	8.4	8.4
	25	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
21	0	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
	5	8.3	8.3	8.3	8.3	8.3	8.3	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
	15	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
	25	8.4	8.4	8.4	8.4	8.4	8.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
28	0	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
	5	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.2	8.2	8.3	8.3	8.3	8.3	8.3	8.3
	15	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
	25	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
35	0	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
	5	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.2	8.2	8.2
	15	8.4	8.4	8.4	8.4	8.3	8.3	8.4	8.3	8.3	8.4	8.4	8.4	8.4	8.4	8.4
	25	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
42	0	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
	5	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.2	8.2	8.2
	15	8.4	8.4	8.4	8.4	8.3	8.3	8.3	8.3	8.3	8.4	8.4	8.4	8.4	8.4	8.4
	25	8.5	8.5	8.5	8.5	8.4	8.4	8.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
49	0	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
	5	8.2	8.2	8.2	8.2	8.2	8.2	8.3	8.3	8.2	8.3	8.3	8.3	8.3	8.3	8.3
	15	8.4	8.4	8.4	8.4	8.4	8.4	8.3	8.4	8.3	8.4	8.4	8.4	8.4	8.4	8.4
	25	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.4	8.4	8.4	8.4	8.5	8.5	8.5	8.5
56	0	8.2	8.2	8.2	8.3	8.3	8.2	8.2	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
	5	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
	15	8.4	8.4	8.4	8.4	8.4	8.4	8.3	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
	25	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
63	0	8.2	8.2	8.2	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.2	8.3
	5	8.3	8.3	8.3	8.4	8.3	8.3	8.3	8.3	8.3	8.4	8.3	8.3	8.3	8.3	8.3
	15	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
	25	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5

Table 1: Periodical changes pH in water of aquaria reared with *L. vennamei* at varying salinities and protein sources.

*FM25: Fish meal containing 25% crude protein; FM30: Fish meal containing 30% crude protein; FM35: Fish meal containing 35% crude protein; CSM25: Cottonseed meal containing 25 % crude protein; CSM30: Cottonseed meal containing 30 % crude protein; CSM35: Cottonseed meal containing 35% crude protein; AI25: Acetes indicus meal containing 25% crude protein; AI30: Acetes indicus meal containing 30% crude protein; AI35: Acetes indicus meal containing 35% crude protein; SF25: Sunflower meal containing 25% crude protein; SF30: Sunflower meal containing 30% crude protein; SF35: Sunflower meal containing 35% crude protein; MM25: Mysid meal containing 25% crude protein; MM30: Mysid meal containing 30% crude protein; MM35: Mysid meal containing 35% crude protein.

Culture Days	Salinities (ppt)	FM			CSM			AI			SF			MM		
		FM 25	FM 30	FM 35	CSM 25	CSM 30	CSM 35	AI 25	AI 30	AI 35	SF 25	SF 30	SF 35	MM 25	MM 30	MM 35
0	0	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5
	5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5
	15	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5
	25	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6
7	0	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8
	5	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8
	15	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8
	25	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9
14	0	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5
	5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5
	15	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5
	25	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5
21	0	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1
	5	30.2	30.1	30.1	30.2	30.1	30.1	30.2	30.1	30.1	30.2	30.1	30.1	30.2	30.1	30.1
	15	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1
	25	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2
28	0	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2
	5	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2
	15	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2
	25	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2
35	0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	5	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	15	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	25	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1
42	0	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8
	5	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8
	15	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8	30.8
	25	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.9
49	0	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2
	5	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2
	15	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2
	25	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2
56	0	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3
	5	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3
	15	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3
	25	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3
63	0	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6
	5	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6
	15	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6
	25	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7

Table 2: Water temperature changes recorded (°C) during the rearing of *L. vennamei* under varying salinities and protein sources.

*FM25: Fish meal containing 25% crude protein; FM30: Fish meal containing 30% crude protein; FM35: Fish meal containing 35% crude protein; CSM25: Cottonseed meal containing 25 % crude protein; CSM30: Cottonseed meal containing 30 % crude protein; CSM35: Cottonseed meal containing 35% crude protein; AI25: Acetes indicus meal containing 25% crude protein; AI30: Acetes indicus meal containing 30% crude protein; AI35: Acetes indicus meal containing 35% crude protein; SF25: Sunflower meal containing 25% crude protein; SF30: Sunflower meal containing 30% crude protein; SF35: Sunflower meal containing 35% crude protein; MM25: Mysid meal containing 25% crude protein; MM30: Mysid meal containing 30% crude protein; MM35: Mysid meal containing 35% crude protein.

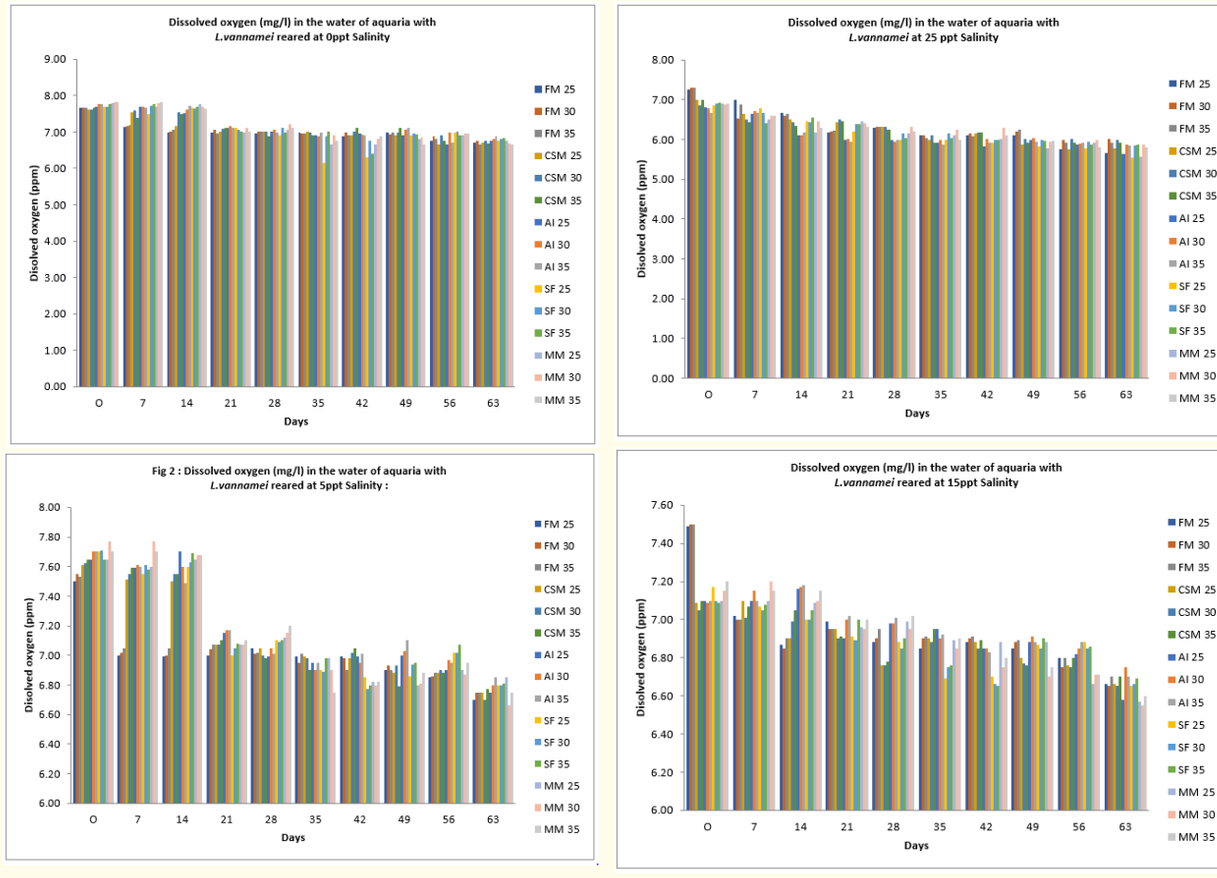
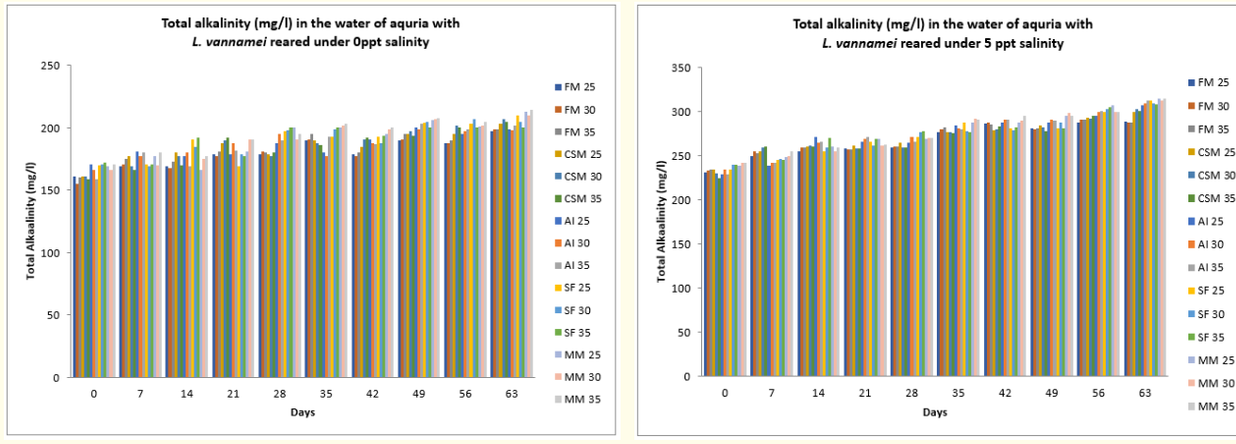


Figure 1: Periodical changes in the water dissolved oxygen content (mg l-1) of L. vannamei reared in varying salinities and protein sources.

*FM25: Fish meal containing 25% crude protein; FM30: Fish meal containing 30% crude protein; FM35: Fish meal containing 35% crude protein; CSM25: Cottonseed meal containing 25 % crude protein; CSM30: Cottonseed meal containing 30 % crude protein; CSM35: Cottonseed meal containing 35% crude protein; AI25: Acetes indicus meal containing 25% crude protein; AI30: Acetes indicus meal containing 30% crude protein; AI35: Acetes indicus meal containing 35% crude protein; SF25: Sunflower meal containing 25% crude protein; SF30: Sunflower meal containing 30% crude protein; SF35: Sunflower meal containing 35% crude protein; MM25: Mysid meal containing 25% crude protein; MM30: Mysid meal containing 30% crude protein; MM35: Mysid meal containing 35% crude protein.



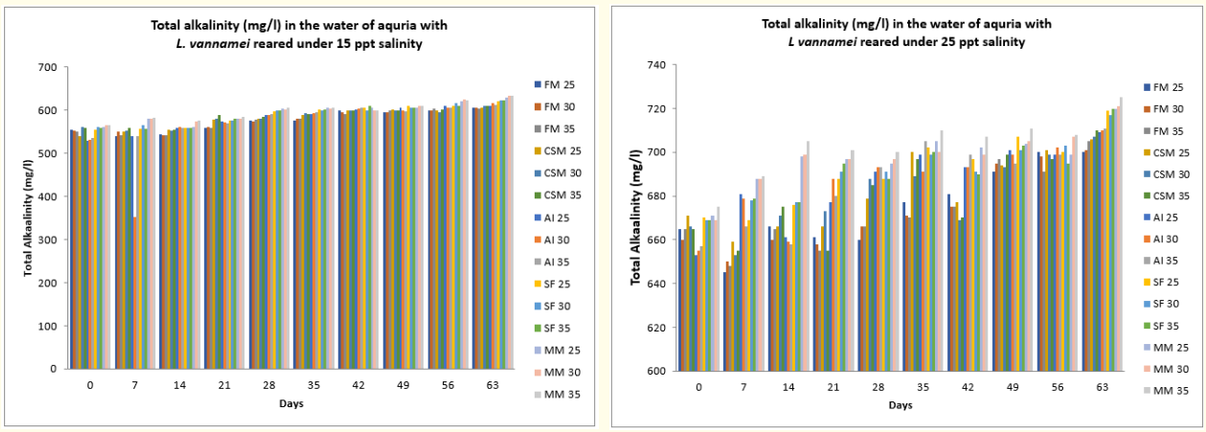


Figure 2: Periodical changes in the water alkalinity (mg l-1) of L. vannamei reared in varying salinities and protein sources.

*FM25: Fish meal containing 25% crude protein; FM30: Fish meal containing 30% crude protein; FM35: Fish meal containing 35% crude protein; CSM25: Cottonseed meal containing 25 % crude protein; CSM30: Cottonseed meal containing 30 % crude protein; CSM35: Cottonseed meal containing 35% crude protein; AI25: Acetes indicus meal containing 25% crude protein; AI30: Acetes indicus meal containing 30% crude protein; AI35: Acetes indicus meal containing 35% crude protein; SF25: Sunflower meal containing 25% crude protein; SF30: Sunflower meal containing 30% crude protein; SF35: Sunflower meal containing 35% crude protein; MM25: Mysid meal containing 25% crude protein; MM30: Mysid meal containing 30% crude protein; MM35: Mysid meal containing 35% crude protein.

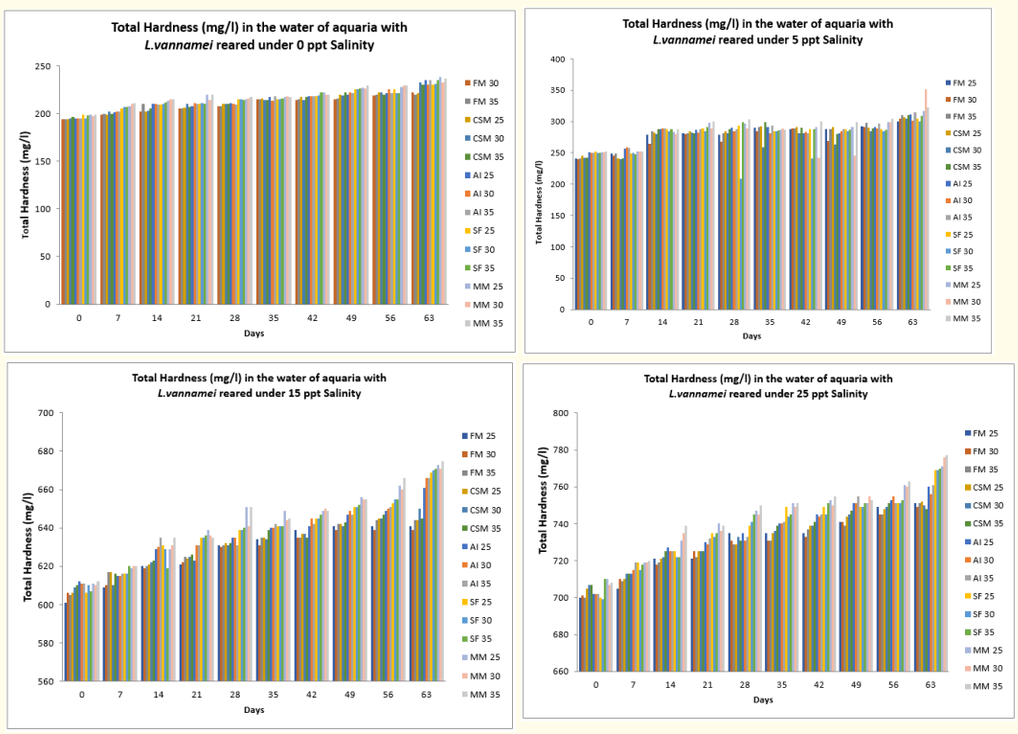


Figure 3: Periodical changes in the water hardness (mg l-1) of *L. vannamei* reared in varying salinities and protein sources.

*FM25: Fish meal containing 25% crude protein; FM30: Fish meal containing 30% crude protein; FM35: Fish meal containing 35% crude protein; CSM25: Cottonseed meal containing 25 % crude protein; CSM30: Cottonseed meal containing 30 % crude protein; CSM35: Cottonseed meal containing 35% crude protein; AI25: Acetes indicus meal containing 25% crude protein; AI30: Acetes indicus meal containing 30% crude protein; AI35: Acetes indicus meal containing 35% crude protein; SF25: Sunflower meal containing 25% crude protein; SF30: Sunflower meal containing 30% crude protein; SF35: Sunflower meal containing 35% crude protein; MM25: Mysid meal containing 25% crude protein; MM30: Mysid meal containing 30% crude protein; MM35: Mysid meal containing 35% crude protein.

Conclusion

In conclusion, the study recommended the feasibility of culture of *L. vannamei* up to 25 ppt salinity as most of the water quality parameters are within the suitable ranges coupled with little fluctuation among the treatments, irrespective of different dietary protein diets and growth.

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