ARTICLE

Effects of ionic composition on growth and survival of white shrimp *Litopenaeus vannamei* culture at low-salinity well water

Efecto de la composición iónica sobre el crecimiento y la supervivencia de camarón blanco *Litopenaeus vannamei* cultivado en agua de pozo de baja salinidad

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Resumen.- El cultivo de camarón blanco *Litopenaeus vannamei* en agua con baja salinidad (1,2 ± 0,5 g L^{-1}) y con diferente composición iónica afecta el desempeño de los organismos en cultivo. El efecto de cultivar en agua de baja salinidad con diferente contenido de iones fue evaluado en crecimiento y supervivencia del camarón. Cuatro pozos de diferente composición iónica del agua fueron seleccionados en el Río Sinaloa, Guasave, México, localizados en: (T_1) 25,43°N, 108,44°W; (T_2) 25,48°N, 108,37°W; (T_3) 25,60°N, 108,40°W y (T_4) 25,64°N, 108,51°W. El diseño experimental fueron 4 tratamientos con 3 réplicas. También se cultivó camarón en agua de mar (T_m= 34 ± 1,4 g L^{-1}) como control. El camarón cultivado en T_m y T_1 alcanzaron peso promedio superior a 12 g y tasa de supervivencia del 78%, con diferencias significativas a los demás tratamientos de agua de baja salinidad. El factor de condición obtenida con agua de baja salinidad (T_1= 0,654) fue similar al registrado para T_m (0,670), donde las proporciones iónicas (Na/K y Mg/K) fueron similares en ambos. Esta última observación sugiere que las proporciones de los principales iones (Na$^+$, K$^+$, Mg^{2+} y Ca^{2+}) juegan un papel relevante para el desarrollo de los organismos bajo cultivo. Cuando la relación iónica fue similar a la del agua de mar, se obtuvieron organismos con el mejor desarrollo, indicando que la proporción de iones mayores fueron importantes para el crecimiento y desempeño del camarón en cultivo.

Palabras clave: *Litopenaeus vannamei*, composición iónica, agua de pozo de baja salinidad

Abstract.- The culture of white shrimp *Litopenaeus vannamei* in low salinity waters (1.2 ± 0.5 g L^{-1}) presents challenges, the deviation of the ionic composition of water is known that influences the overall condition of the cultured organisms. The effect of water of low salinity with different ion content on the growth and survival of shrimp was determined. First, water was extracted from 4 wells with a depth of 5 to 7 m, located in Sinaloa River Basin in Guasave, Mexico at: (T_1) 25.43°N, 108.44°W; (T_2) 25.48°N, 108.37°W; (T_3) 25.60°N, 108.40°W and (T_4) 25.64°N, 108.51°W and were selected on base the different ionic water composition. The experimental design was 4 independent treatments with 3 replicate. Shrimp were grown at sea water (T_m = 34 ± 1.4 g L^{-1}) used as a control. Shrimps grown in T_m and T_1 had averaged weight (over 12 ± 0.61 g) and survival rates (78%), with statistical differences to others low salinity water treatments. The condition factor obtained with low-salinity water (T_1= 0.654) was like that recorded for T_m (0.670), where ionic ratios (Na/K and Mg/K) were similar to that of seawater. This observation strongly suggests that the ratios of the major ions (Na$^+$, K$^+$, Mg^{2+} and Ca^{2+}) play a relevant role for development of organisms under cultivation. Shrimp cultured in water of low salinity with an ionic ratio similar to that of sea water were organisms with the best development under cultivation, therefore indicating that the proportion of major ions were important for shrimp.

Key words: *Litopenaeus vannamei*, ionic composition, low-salinity well water

INTRODUCTION

In order to optimize the shrimp culture with water of low salinity is necessary to assess the impact of the variability in the ionic composition of water on the general condition of the organisms (Gong *et al.* 2004, Gullian *et al.* 2010). The shrimp industry in the United States of America (Roy *et al.* 2010), Brazil (Nunes & Lopez 2001), Thailand (Saoud *et al.* 2003, Roy *et al.* 2007), China (Cheng *et al.* 2005) and Mexico (Godinez-Siordia *et al.* 2011), advanced the cultivation of *Litopenaeus vannamei* (Boone, 1931) in water with salinities less than 5 g L^{-1}. However, still lack of information regarding the condition and survival of

the shrimp *L. vannamei* in a full cycle culture, in response to growing with well water or surface water with low salinity and different ion profile (Gullian *et al*. 2010). Shrimp aquaculture presents challenges such as determining how water ionic conditions limit productive potential of shrimp species in each farm regions.

The ionic composition and salinity of water can vary widely between sites, so in some regions, natural sources of low-salinity water cannot be used directly for shrimp culture (Davis *et al*. 2002, Saoud *et al*. 2003, Zhu *et al*. 2006). In some cases, there are low levels of potassium, magnesium and other ions, or deviations in the proportions of the ionic compositions, which limit the development of shrimp crops. The ions (calcium, sodium, potassium and chloride) play a basic role in the osmoregulatory process and intervene on the maintenance of membrane potentials (Mantel & Farmer 1983, Pequeux 1995). Shrimp require minerals to maintain basal metabolism and growth. Soluble minerals are constituents of tissues, enzymatic cofactors and play a role in metabolism of lipids, proteins and carbohydrates (Davis & Lawrence 1997) and, the same authors, suggested to add as dietary supplements in shrimp reared in low salinity water.

It has been experimentally determined that when there is a deviation in the concentration of essential ions in relation to those found in seawater, such as K^+ and Mg^{2+}, growth and survival of *L. vannamei* in both acclimation (Saoud *et al*. 2003) and growing (Samocha *et al*. 2004) conditions are limited. Boyd (1989) reported that salinities between 15 and 25 g L^{-1} are ideal for growing white shrimp *L. vannamei*, whilst Samocha *et al*. (2004) reported that cultivating this species in low salinity water (<3 g L^{-1}) could support growths up to 14 g.

Condition factor resultant of the potential equation parameters (Araneda *et al*. 2008) provide an evaluation of the specific conditions under which organisms are developing and can be valuable to culture system management because differently factors can affect isometry. Last, interpreted like equality of growth rates in two parts in the growth stage organisms (Chow & Sandifer 1991). The condition factor (CF) determined from Fulton's equation (Ricker 1979, Chow & Sandifer 1991) to evaluate the effect on a specific characteristic in which shrimp farming developed. The proportionality of length (cm) and weight (g) were tested in the juvenile growing shrimp. Alteration in the expected relationship of isometric growth (b= 3) may be usually considered as an indicator of change in the physical or physiological well-being of the individuals under study. When this relationship is diverted to the allometric growth (b < 3), the physiological status could be interpreted as negative (Pauly 1984), because that population is tend to maintain a slower growth, smaller size, lower survival and hence low productive

performance. Positive allometric (b > 3) organisms have the added advantage of growing more in weight than in length (Araneda *et al*. 2008).

The objective of this research was to determine the effect of 4 sources of well water of low salinity with different ionic composition on growth, survival and condition factor (CF) of juvenile marine shrimp *L. vannamei* cultured at high density.

MATERIALS AND METHODS

ORIGIN OF WATER USED IN THE EXPERIMENTAL WORK

The experimental work was performed using 4 sources of well water with low salinity and different ionic composition. The water was extracted from 4 wells with a depth of 5 to 7 m, which were located in Sinaloa River Basin (25.3-26.5°N, 106.7-108.5°W) in Guasave, Mexico. The wells are located at the following coordinates (i) 1 to 4 (Ti): (T_1) 25.43°N, 108.44°W; (T_2) 25.48°N, 108.37°W; (T_3) 25.60°N, 108.40°W and (T_4) 25.64°N, 108.51°W.

EXPERIMENTAL DESIGN

The experimental work was designed to compare the effect of the ionic composition of different sources of well water on productive parameters and condition factor (CF) of juvenile marine shrimp *Litopenaeus vannamei*, stocked at a density of 150 organism m^{-2}. The culture was conducted in a greenhouse in 15 fiberglass containers (1m x 1m x 1m). Treatments (T_1, T_2, T_3 and T_4) and the control group (T_m) each with 3 replicates operated as separate systems. In the T_m shrimp was grown using seawater (34.0 ± 0.5 g L^{-1}) under the same conditions of treatment with well water. To maintain the water quality each experimental unit received a daily water exchange of 10%. The shrimp are grown in natural photoperiods (14 h light/ 10 h dark). Each of the containers was maintained with constant aeration to meet dissolved oxygen (DO) requirements (4-5 mg L^{-1}).

MAINTENANCE, STOCKING AND REARING OF EXPERIMENTAL ORGANISMS

A single batch of shrimp postlarvae *L. vannamei* (PL_{20}) was obtained from a commercial laboratory and stocked in a fiberglass tank (2,600 L); they remained for 3 days at a salinity of 34 ± 0.5 g L^{-1}, with constant water flow (0.6 L min^{-1}) and aeration. Prior to the start of the experiment, shrimp were acclimated from seawater (34.0 ± 0.5 g L^{-1}) until to reach to the salinity of each of the respective wells (Fig. 1, Table 1) with a rate of change of 0.25 g L^{-1} h (McGraw & Scarpa 2004, Esparza-Leal *et al*. 2010). Subsequently, the shrimp postlarvae (0.012 ± 0.004 g) were stocked into tanks.
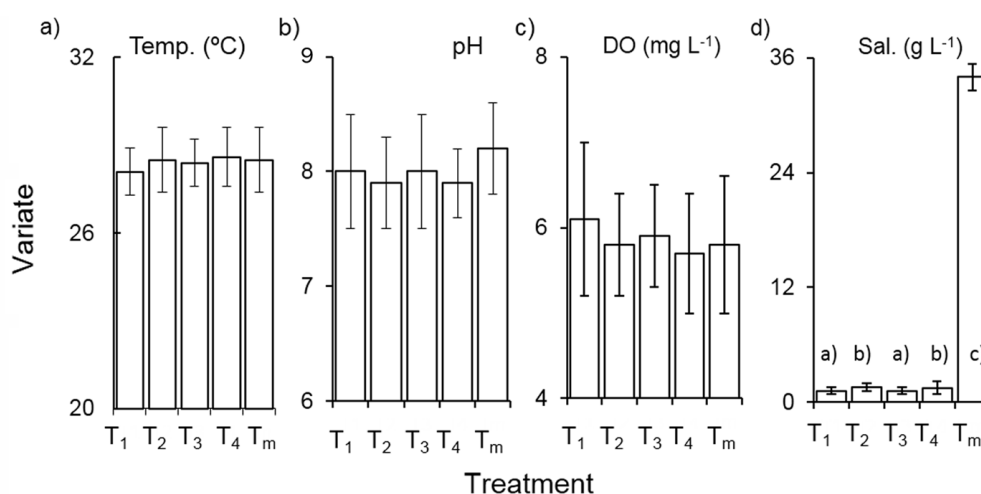
Figure 1. Means (± SD) of water parameters from different sources of low salinity well water and seawater (control) throughout culture period. Water sources: (T₁) 25.43°N, 108.44°W; (T₂) 25.48°N, 108.37°W; (T₃) 25.60°N, 108.40°W; (T₄) 25.64°N, 108.51°W and Tₘ, seawater at 25.303°N, 108.533°W / Medias (± DE) de los parámetros de agua de pozo con baja salinidad de diferente origen y del agua de mar (control) a lo largo período de cultivo. Los pozos de agua se localizaron: (T₁) 25,43°N, 108,44°O; (T₂) 25,48°N, 108,37°O; (T₃) 25,60°N, 108,40°O; (T₄) 25,64°N, 108,51°O y (Tₘ) agua de mar en 25,303°N, 108,533°O

Table 1. Mean (± SD) concentrations of major ions and ratios of different sources of low salinity well water (T₁-T₄) and seawater (Tₘ) throughout culture period / Media (± DE) de las concentraciones y proporciones de los iones principales de las diferentes fuentes de agua de baja salinidad (T₁-T₄) y el agua de mar (Tₘ) a lo largo período de cultivo

Ions (mg L⁻¹)	Water source (Treatments)				
	T_1	T_2	T_3	T_4	T_m*
Anions					
Bicarbonates	303.4±50.8	296.0±30.5	309.2±40.6	333.6±27.6	142
Chloride	27.0±7.3^a	120.3±21.8^c	42.1±10.2^b	122.5±26.1^c	19,000
Sulfate	65.4 ±13.1^a	196.1±33.4^b	50.4±17.4^a	53.0±10.2^a	2,700
Cations					
Calcium	56.8±17.4^b	198.5±46.4^d	34.0±8.7^a	85.6±11.6^c	400
Magnesium	14.7±4.4^a	137.9±27.6^c	40.6±13.1^b	53.8±17.4^b	1,360
Sodium	142.2±31.9^b	48.7±11.6^a	124.8±24.7^b	159.0±27.6^b	10,500
Potassium	4.7 ±2.2^c	6.8±3.1^c	0.77±0.3^a	2.08±0.7^b	370
Ratios					
Na/K	30.9:1^b	7.4:1^a	162.5:1^d	76.3:1^c	28.3:1
Ca/K	12.3:1^a	29.3:1^b	44.1:1^b	41.4:1^b	1.08:1
Mg/Ca	0.26:1^a	0.69:1^b	1.19:1^b	0.63:1^a	3.4:1
Mg/K	3.1:1^a	20.1:1^b	52.5:1^c	25.5:1^b	3.6:1

Different superscripts letters in row indicate significant differences ($P < 0.05$)
Water Source: (T₁) 25.43°N, 108.44°W; (T₂) 25.48°N, 108.37°W; (T₃) 25.60°N, 108.40°W; (T₄) 25.64°N, 108.51°W and seawater (Tₘ) at 25.303°N, 108.533°W. * Goldberg, 1963

During both the acclimation and study (150 organism m^{-2}), organisms were fed with commercial food (35% protein, Ralston Purina ration) 3 times a day (08:00, 12:00 and 16:00 h). The feeding rates for each group of organisms were weekly adjusted in relation to the amount of uneaten food (Cuadros & Beltrame 1998). The feeding rates started at 18% of the biomass estimated of PL and progressively reduced to 2% when the organism has reached an average weight of about 12 g.

Water quality and major ion analyses

Temperature (°C), dissolved oxygen (DO, mg L^{-1}), and pH were recorded daily at 08:00 and 16:00 h using a standard mercury thermometer, a YSI 55 oxygen meter (Yellow Springs Instrument, Yellow Springs, OH, USA) and a potentiometer Hanna 213, respectively. Salinity was measured using a YSI 556 multi-parameter equipped with a conductivity-salinity probe (YSI ProDSS Multiparameter, Yellow Springs, Ohio, USA); additionally, it was corroborated using the criteria of Boyd *et al.* (2002). Every two weeks water samples were taken from each of the experimental units to analyze the concentration of nitrite (N-NO$_2^-$), nitrate (N-NO$_3^-$), total ammonia-N (N-NH$_3$) and phosphate (PO$_4$-P) with the methods described by Arredondo-Figueroa & Ponce-Palafox (1998).

Twice a monthly 500 ml of water of each treatment were transported to a certified laboratory by the Mexican Federal Authorities (CNA Reg. No. CAN-GSCA-440), to analyze the concentration of major ions: bicarbonate (HCO$_3^-$), chloride (Cl$^-$), sulfate (SO$_4^{2-}$), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K$^+$) and sodium (Na$^+$), using standard protocols described by Clesceri *et al.* (1998).

Growth, length-weight relationship, condition factor and survival

Weekly, 50 shrimp were collected randomly from each treatment, to record length (mm) and weight (g). Total length of shrimp (rostrum to telson distance) was measured by means of an ichthyometer (±1 mm, Aquatic FMB2, Aquatic Eco-Systems FL, USA) and weight was recorded using a digital scale (± 0.01 g, Ohaus IL, USA).

The information obtained was used to calculate the length-weight relationship of the organisms from each treatment, using a potential model (W$_i$= a TL$_i^b$), where i = treatment, Wi= weight (g), TLi= total length (mm), a= proportionality constant and b = exponent of the equation.

The Fulton's equation (Ricker 1979, Chow & Sandifer 1991) was used to determine the condition factor of each group:

$$CF_i = \frac{\overline{W}_i}{\overline{TL}^3}\ 10^5$$

where CFi =condition factor for treatment i, $\overline{W}_i$= average weight (g) and $\overline{TL}$ = average total length (mm).

The experiment concluded after 133 days at which time all shrimp from each tank were harvested, measured (length and weight), and counted to calculate survival, growth (g), production (kg m^{-2}) and feed conversion rate (FCR) were estimated.

Statistical analysis

Data was analyzed to determine whether there were significant differences between the treatments in growth, survival, production, water quality, and concentration of major ions. They were analyzed using a one-way variance test. Comparisons were made between treatments using Student-Newman-Keuls test. Data are expressed as mean ± standard deviation.

A non-linear regression analysis was used to determine the length-weight relationship. The curves potential resulting from each treatment were compared with one-way analysis of covariance (ANCOVA) and *a posteriori* Tukey test. The statistical significance of the exponent from equation (b) was analyzed using the function proposed by Pauly (1984):

$$\hat{t} = \frac{s.\,d.\,(x)}{s.\,d.\,(y)}\ \frac{|b_i - 3|}{\sqrt[2]{1 - r^2}}\ \sqrt[2]{n_i - 2}$$

where $\hat{t}$ is the t-student statistic, s. d. (x) and (y) are the standard deviation for TL$_i$ and W$_i$ of each treatment, n$_i$ is the number of recorded organisms, b$_i$ is the fitted value of b for treatment, and r^2 is the coefficient of determination. Statistical significance was $\alpha \leq 0.05$.

Results

Water quality

During the experimental work, there were no significant differences between water quality variables, except for salinity ($P > 0.05$, Fig. 1). The average temperature, DO and pH were 28.5°C, 5.9 mg L^{-1} and 8.0, respectively (Fig. 1). The minimum and maximum concentrations of total N-NH$_3$ ranged from 0.26 to 0.31 mg L^{-1}, N-NO$_2$ (0.28 to 0.32 mg L^{-1}), N-NO$_3$ (0.73 to 0.77 mg L^{-1}) and PO$_4$-P (1.5 to 1.7 mg L^{-1}), respectively (Fig. 2). The salinity of each treatment of the different well water source ranged from 1.1 to 1.5 g L^{-1}, while the control group (T$_m$) remained at an average of 34.0 g L^{-1}, presenting significant differences between treatments: T$_1$-T$_3$ with T$_2$-T$_4$ and both with T$_m$ ($P < 0.05$; Fig. 1d).
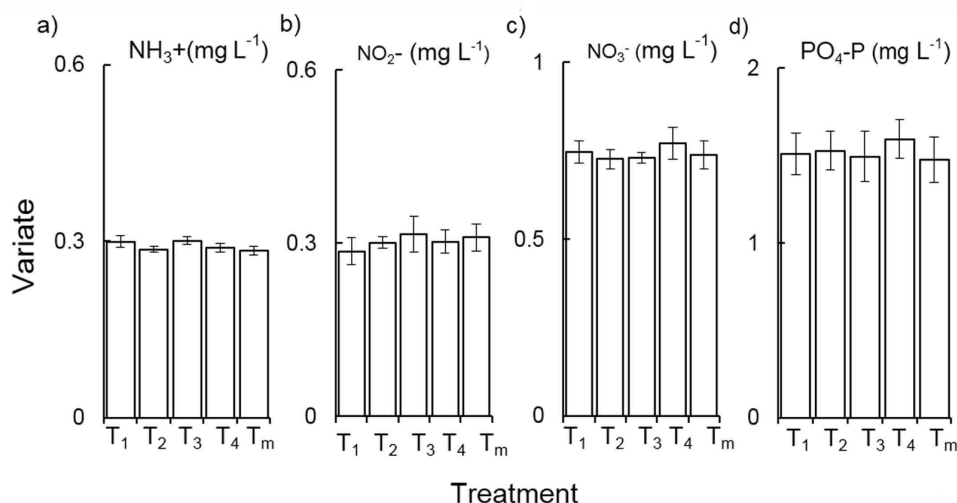
Figure 2. Mean (± SD) nitrateN and phosphateP concentration in water from different sources of low salinity well water and seawater (control) throughout culture period. Water sources: (T_1) 25.43°N, 108.44°W; (T_2) 25.48°N, 108.37°W; (T_3) 25.60°N, 108.40°W; (T_4) 25.64°N, 108.51°W and T_m, seawater at 25.303°N, 108.533°W / Concentración media (± DE) de nitrato-N y fostato-P en agua de pozo de diferente origen con baja salinidad y del agua de mar (control) a lo largo período de cultivo. Los pozos de agua se localizaron: (T_1) 25,43°N, 108,44°O; (T_2) 25,48°N, 108,37°O; (T_3) 25,60°N, 108,.40°O; (T_4) 25,64°N, 108,51°O y (T_m) agua de mar en 25,303°N, 108,533°O

MAJOR IONS CONCENTRATIONS AND RATIOS

All treatments of low salinity well water had values of bicarbonate (HCO_3^-) over 296.0 ± 30.5 mg L^{-1} (T_1) and were higher than in the control group (sea water, T_m) = 142 mg L^{-1} (Table 1). Chloride concentration (Cl^-) was between 27.0 ± 7.3 (T_1) to 122.5 ± 26.1 mg L^{-1} (T_2), all water source was different (Table 1). In all the following cases: Calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+) and sulfate (SO_4^{2-}) (Table 1) the concentrations were lower than T_m, all showing significant statistically differences ($P < 0.05$).

The ionic ratios for Na/K at T_1, T_3 and T_4 were highest that T_m. Ratios of Mg/K and Ca/K were higher in all treatment of well water; conversely, T_m showed higher ratios of Mg/Ca than the others (Table 1).

GROWTH, SURVIVAL AND PRODUCTION

Higher values of weight (13.3 ± 0.61 g), survival ($84.6 \pm 4.1\%$) and production (1.70 ± 0.18 kg m^{-2}) were recorded in T_m, followed for T_1 for the same zootechnical parameters (Table 2). The lowest values of weight ($T_3 = 10.8 \pm 1.05$ g), survival ($T_4 = 76.35 \pm 3.69\%$) and production (T_3 and $T_4 = 1.25$ kg m^{-2}) occurred in different well water treatments (Table 2). There were significant differences between the final weight ($F_{(4,1841)} = 4.28$; $P < 0.05$) and production ($F_{(4,14)} = 7.28$; P <0.05) of treatments T_2, T_3 and T_4 in relation to T_1 and T_m (Table 2).

LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR

The coefficients of determination (R^2) obtained in this study ranged between 0.95 and 0.99, indicating that the potential model used was adequate for the length-weight relationship (Fig. 3, Table 3). The greater exponent (*b*) appeared in T_3 (3.151), followed by T_m (3.046) and T_1 (3.012). ANCOVA analysis determined that the slopes of the potential models for the length-weight relationship were significantly different between treatments ($F= 21.2$; $P < 0.05$). The highest condition factor occurred in farmed shrimp with T_1 (0.711) and T_m (0.700), both were isometric and based on $\hat{t}$, there were no different from 3 ($t= 1.96$ $P < 0.05$, Table 3). Condition factor values at treatments T_2, T_3 and T_4 were the lowest for shrimp culture; the slopes differed from 3, regarding the statistic (Table 3), and were consequently allometric.

DISCUSSION

WATER QUALITY

The water quality variables (T, DO, pH, N-NO_2^-, N-NO_3^-, N-NH_3 and PO_4-P) remained at levels appropriate for the shrimp *Litopenaeus vannamei*, as reported by other authors (Arredondo-Figueroa & Ponce-Palafox 1998, Atwood *et al.* 2003, Saoud *et al.* 2003) and the temperature (28°C, Fig. 1) was on the termal preferendum of 27-30ºC for juvenile shrimps (Ponce-Palafox *et al.* 1997, Hernández *et al.* 2006).

Table 2. Mean (± SD) values of the indicators of *L. vannamei* reared in 4 different sources of low salinity well water and seawater (control) using PL_{25} socked at density of 150 shrimp m^{-2} for 133 days / Media (± DE) de los indicadores de *L. vannamei* cultivados en 4 diferentes fuentes de agua de baja salinidad y agua de mar (control) utilizando PL_{25} a una densidad de 150 camarones m^{-2} por 133 días de cultivo

Treatment (Water source)	Initial weight (g)	Final weight (g)	FCR	Survival (%)	Crop (Kg m^{-2})
T_1	0.013 ± 0.0013	$12.8^b \pm 0.93$	1.55 ± 0.24	$78.4^a \pm 3.7$	$1.50^b \pm 0.18$
T_2	0.014 ± 0.0012	$11.6^a \pm 1.10$	1.71 ± 0.23	$77.6^a \pm 3.4$	$1.31^a \pm 0.20$
T_3	0.012 ± 0.0013	$10.8^a \pm 1.05$	1.78 ± 0.15	$78.6^a \pm 4.3$	$1.25^a \pm 0.10$
T_4	0.013 ± 0.0011	$11.2^a \pm 0.91$	1.68 ± 0.19	$76.4^a \pm 3.7$	$1.25^a \pm 0.21$
T_m	0.012 ± 0.0012	$13.3^b \pm 0.61$	1.58 ± 0.10	$84.6^b \pm 4.1$	$1.70^b \pm 0.18$

FCR. Feed Conversion Rate
Different superscripts letters within rows indicate significant differences ($P < 0.05$)
Water source: (T_1) 25.43°N, 108.44°W; (T_2) 25.48°N, 108.37°W; (T_3) 25.60°N, 108.40°W and (T_4) at 25.64°N, 108.51°W and seawater (T_m) 25.303°N, 108.533°W
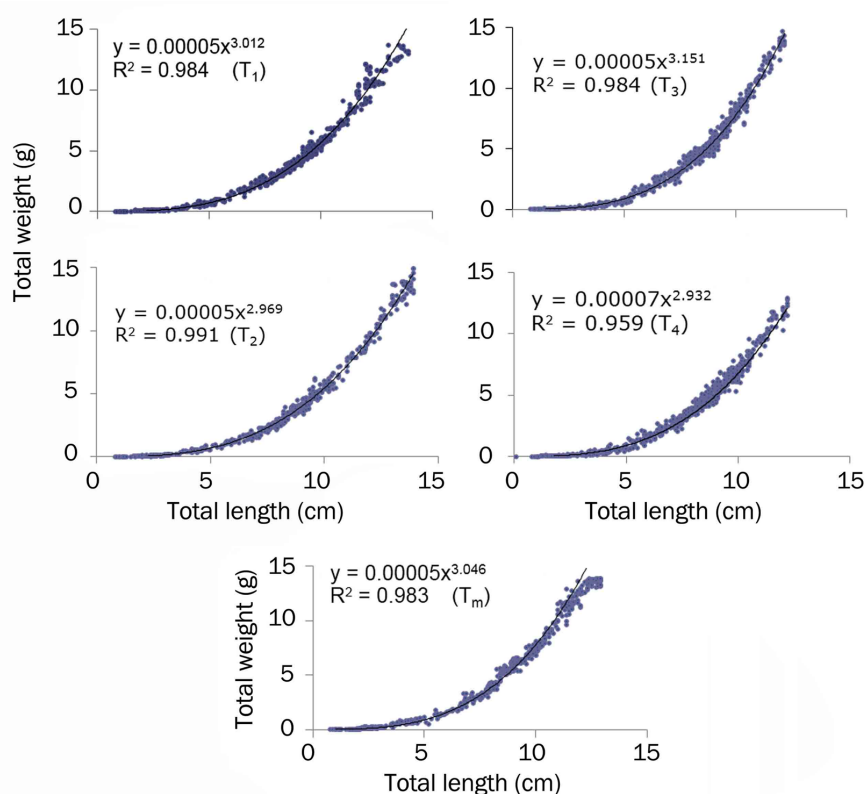

Figure 3. Length-weight relationship for white shrimp grown, using PL_{25} stocked at density of 150 shrimp m^{-2} by 133 days. Water source: (T_1) 25.43°N, 108.44°W; (T_2) 25.48°N, 108.37°W; (T_3) 25.60°N, 108.40°W y (T_4) 25.64°N, 108.51°W and (T_m) seawater at 25.303°N, 108.533°W. **Each circle represents an observation** / Relación talla-peso para camarón blanco cultivado, usando PL_{25} y sembrado a densidad de 150 camarones m^{-2} durante 133 días. Los pozos de agua se localizan: (T_1) 25,43°N, 108,44°O; (T_2) 25,48°N, 108,37°O; (T_3) 25,60°N, 108,40°O; (T_4) 25,64°N, 108,51°O y (T_m) agua de mar en 25,303°N, 108,533°O. Cada círculo representa una observación

Table 3. Regression estimates (*b*) for length-weight and condition factor (CF) of *L. vannamei* reared in 4 different sources of low salinity well water and seawater (Control) using PL$_{25}$ socked at density of 150 shrimp m^{-2} by 133 days / Valores de regresión (*b*) para la longitud-peso y factor de condición (CF) de *L. vannamei* cultivado en 4 diferentes fuentes de agua de baja salinidad y agua de mar (control) utilizando PL$_{25}$ una densidad de 150 camarones m^{-2} por 133 días

Treatment water source	Coefficient (*b*)	R^2	S.D. (*y*)	S.D. (*x*)	Condition factor (CF)	$^*\hat{t}$
T_1	3.012	0.984	1.06	0.47	0.711	1.017
T_2	2.969	0.991	1.51	0.58	0.644	2.869
T_3	3.151	0.984	4.36	0.84	0.495	5.677
T_4	2.932	0.959	2.02	0.85	0.598	3.385
T_m	3.046	0.983	1.85	0.45	0.700	1.959

$^*\hat{t}$ is the *t*-student statistic. S.D. (x) and (y) are the standard deviation for final total length TL_i and weight W_i of each treatment. Water source: (T_1) 25.43°N, 108.44°W; 25.48°N, 108.37°W; (T_3) 25.60°N, 108.40°W and (T_4) at 25.64°N, 108.51°W and seawater (T_m) at 25.303°N, 108.533°W

Temperature is an important factor that influence growth rates of penaeid shrimp (Tsuzuki *et al.* 2000). In addition, the nitrogen compounds, for juvenile *L. vannamei* grown in water of 2 g L^{-1} of salinity (Gross *et al.* 2004) suggest a safe concentration for shrimp production in ponds less than 0.45 mg L^{-1} NO$_2$-N. In this work, shrimp exposed to nitrite and ammonia concentration of 3 mg L^{-1} combined with low chloride for long time could reduce their growth and affect their survival.

GROWTH, SURVIVAL AND PRODUCTION

Growth rates of 0.61 g week^{-1} at a stocked density of 150 organism m^{-2} were recorded for the groups, while T$_m$ reached a growth rate of 0.67 g week^{-1}. In nature, this species is able to grow at 1.4 g week^{-1} at densities of 2-3 shrimp m^{-2} (Menz & Blake 1980 *fide* Wyban & Sweeney 1989). There were significant differences in growth rates of farmed shrimp in T$_1$ with the other different ionic profile treatments. The slower growth in T$_3$ was obtained (0.57 g week^{-1}) where concentrations of potassium (0.58 mg L^{-1}) and calcium (28.00 mg L^{-1}) were lower than other treatments. A trend of greater shrimp growth was observed within the ratio values of Na/K (T$_1$= 30.9) and Mg/K (T$_1$= 3.1), which were similar to that of seawater (T$_m$; Na/K= 28.1 and Mg/K= 3.6). The water ionic profile may vary from each well in different areas (Boyd & Thunjai 2003). This indicates that to grow *L. vannamei* with well water it is important to account for ionic ratios and water salinity values (Saoud *et al.* 2003, Esparza-Leal *et al.* 2010). Other indicator is estimating acceptable concentrations of individual ions for brackish water shrimp culture, proposed by Boyd et al. (2002); in this case, any treatment was similar to that estimate of seawater. However, the minimum acceptable concentration of total alkalinity as bicarbonate at all cases was over about 300 mg L^{-1} (Boyd & Tucker 1998); this condition avoids shrimp has difficulty molting.

Shrimp culture with different source of well water has a mean survival of 77%. Regardless of salinity content, the ionic water profile is a variable that significantly influences the survival of shrimp (Davis *et al.* 2002, Saoud *et al.* 2003, Zhu *et al.* 2004). Farmed shrimp with different ion profiles on water achieved better growth and survival in the Na/K ratio similar to seawater (Roy 2006). In several experiments, Roy *et al.* (2007) observed better survival and average individual weight of postlarvae, when the culture water approximates to Na/K ratio of 28:1, similar to seawater. Also, Roy *et al.* (2007) found that growing juvenile shrimp in reconstituted seawater (4 g L^{-1}) in the treatment of 40 mg K$^+$ L^{-1} sustaining a significantly higher weight gain compared to low K$^+$ concentrations. An additional experiment, reference water (control) and treatment of 40 mg K$^+$ L^{-1} maintained Na/K ratios of 29:1 and 30:1, respectively. In concordance with Roy *et al.* (2010) the adequate concentrations of essential ions, including potassium (K$^+$) and magnesium (Mg^{2+}), support better growth and survival of shrimp. Perez-Velazquez *et al.* (2012) conducted an experiment with water temperature of 26 and 30°C and Na$^+$/K$^+$ ratios of 40, 80 and 120:1. Growth of shrimp was significantly higher at the Na$^+$/K$^+$ ratio of 40:1 and shrimp survival were no affected by any Na$^+$/K$^+$ ratio.

Final mean weight of shrimp on treatment 1 and seawater (T$_m$) was higher and there were significant differences in the production of shrimp within treatments. Observed by Al-Ameeri & Cruz (2006) and according to Wang *et al.* (1998), mean final sizes of shrimp have a tendency to decrease with increase stocking density and until the carrying capacity of the system is reached. Seawater treatment (T$_m$) presented maximum biomass by the end of the experimental run resulting in a higher production per unit area, because higher survival and means final body weight.

LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR

The potential relationship of length-weight was similar in all treatments of this study and corresponds to that reported for Penaeid species (Dall *et al.* 1990). Reports indicate that when coefficient *b* is equal to 3, isometric growth is observed. Wootton (1992) reported that growth is positive-allometric when the weight of organisms increases more than the length (b > 3) and negative-allometric when the length is greater than the weight (*b* < 3). In this study the organisms of treatments T_1 and T_m showed isometric growth. While for organisms of treatments T_2 (*b*= 2.969) and T_4 (*b*= 2.932), the growth revealed to be negative-allometric. T_3 proved positive-allometric (*b*= 3.151). The length-weight relationship was not proportioned between cultured organisms on well water treatments, probably because of their dissimilar proportionality ion ratios that can affect the growth of organisms (Roy *et al.* 2007). Effect of ion ratios on growth rates could be hidden by the density effect (stocked at a density of 150 organism m^{-2}), given that shrimp growth depends heavily on the latter (Murphy *et al.* 1991).

Growths to those organisms cultured in seawater (T_m) and T_1 were no different, moreover at those treatments ionic ratios for Na/K and Mg/K were statistically similar from seawater. Concentrations of all ions possibly enhanced survival and growth, but after using factors presented by Boyd *et al.* (2002) any treatment was similar with calculated concentrations. McNevin *et al.* (2004) assume that higher potassium concentrations were mainly responsible for superior survival and growth. In this experiment potassium in all treatments was lower that calculated to conserved proportionality at seawater (Castille & Lawrence 1981, Ferraris *et al.* 1986, Parado-Estepa *et al.* 1987), suggesting that most important ions in osmoregulation are chloride and sodium, but the effect of these two ions was important on growth and survival when ionic ratios were near to seawater.

In this analysis, the relationship Na/K (T_1= 30.9) and Mg/K (T_1= 3.1) in low salinity water were similar to that of seawater on conserved proportionality of ions that are considered suitable for growing shrimp. In these conditions the white shrimp can maintain the growth and survival suitable for cultivation. Shrimp cannot compensate for the ionic balance to maintain good growth rates and which consequently condition indices are lower as founded in some treatments (T_4, T_2 and T_3). Also, condition of shrimp obtained in treatments of seawater (T_m) and T_1 was better. Shrimp culture in low salinity well water is one of multiple cause of stress for the marine shrimp *L. vannamei* when the ratio of ions is different from that seawater. Shrimp cultured in water of low salinity with an ionic ratio similar to that of sea water were organisms with the best development under cultivation, therefore indicating that the proportion of ions were important for growth.

LITERATURE CITED

Al-Ameeri AA & EM Cruz. 2006. Production and yield of *Penaeus semisulcatus* (de Haan) cultured at different densities. Aquaculture Research 37: 1499-1506.

Araneda M, EP Pérez & E Gasca-Leyva. 2008. White shrimp *Penaeus vannamei* culture in freshwater at three densities: Condition state based on length and weight. Aquaculture 283: 13-18.

Arredondo-Figueroa JL & JT Ponce-Palafox. 1998. Calidad del agua en acuicultura: conceptos y aplicaciones, 222 pp. AGT Editor, México.

Atwood HL, SP Young, JR Tomasso & CL Browdy. 2003. Survival and growth of Pacific white shrimp *Litopenaeus vannamei* postlarvae in low salinity and mixed salt environments. Journal of the World Aquaculture Society 34: 518-523.

Boyd CE. 1989. Water quality management and aeration in shrimp farming. Fisheries and Allied Aquacultures Departmental Series 2: 1- 83. Alabama Agricultural Experiment Station, Auburn University, Auburn.

Boyd CE & T Thunjai. 2003. Concentrations of major ions in water of inland shrimp farms in China, Ecuador, Thailand and the United States. Journal of the World Aquaculture Society 34: 524-532.

Boyd CE & CS Tucker. 1998. Aquaculture water quality management, 700 pp. Kluwer Academic Publishers, Boston.

Boyd CE, T Thunjai & M Boonyaratpalin. 2002. Dissolved salts in waters for inland, low salinity shrimp culture. Global Aquaculture Advocate 5: 40-45.

Castille FL & AL Lawrence. 1981. The effect of salinity on the osmotic, sodium and chloride concentrations in the hemolymph of euryhaline shrimp of the genus *Penaeus*. Comparative Biochemistry and Physiology, Part A: Molecular & Integrative Physiology 68: 75-80.

Cheng KM, CQ Hu, YN Liu, SX Zheng & XJ Qi. 2005. Effects of dietary calcium, phosphorus and calcium/ phosphorus ratio on the growth and tissue mineralization of *Litopenaeus vannamei* reared in low-salinity water. Aquaculture 251: 472-783.

Chow S & PA Sandifer. 1991. Differences in growth, morphometric traits, and male sexual maturity among Pacific white shrimp, *Penaeus vannamei*, from different commercial hatcheries. Aquaculture 92: 165-179.

Clesceri LS, AE Greenberg & AD Eaton. 1998. Standard methods for the examination of water and wastewater, 1325 pp. American Public Health Association, Washington.

Cuadros W & E Beltrame. 1998. Nuevas técnicas de alimentación con bandejas en el Brasil. Panorama Acuícola 3: 8-9.

Dall W, BJ Hill, PC Rothlisberg & DJ Staples. 1990. The biology of the Penaeidae. Advances in Marine Biology, 489 pp. Academic Press, London.

Davis DA & AL Lawrence. 1997. Minerals. In: D'Abramo LR, DE Conklin & DM Akiyama (eds). Crustacean Nutrition 6: 150-163. World Aquaculture Society, Baton Rouge.

Davis DA, IP Saoud, WJ McGraw & DB Rouse. 2002. Considerations for *Litopenaeus vannamei* reared in inland low salinity waters. In: Cruz-Suárez LE, D Richque-Marie, M Tapia-Salazar, MG Gaxiola-Cortés & N Simoes (eds). Avances en nutrición acuícola, pp. 73-94, Memorias del VI Simposium Internacional de Nutrición Acuícola, 3 al 6 de septiembre del 2002, Cancún, Quintana Roo, México.

Esparza-Leal HM, JT Ponce-Palafox, EA Aragón-Noriega, JL Arredondo-Figueroa, M García-Ulloa-Gómez & W Valenzuela-Quiñonez. 2010. Growth and performance of the whiteleg shrimp *Penaeus vannamei* (Boone) cultured in low-salinity water with different stocking densities and acclimation times. Aquaculture Research 41: 878-883.

Ferraris RP, FD Parado-Estepa, JM Ladja & EG de Jesus. 1986. Effect of salinity on osmotic, chloride, total protein and calcium concentrations in the hemolymph of the prawn *Penaeus monodon* (Fabricius). Comparative Biochemistry and Physiology, Part A: Molecular & Integrative Physiology 83(4): 701-708.

Godinez-Siordia DE, MC Chávez-Sánchez & S Gómez-Jiménez. 2011. Epicontinental aquaculture of the Pacific white shrimp, *Litopenaeus vannamei* (Boone, 1931). Tropical and Subtropical Agroecosystem 14: 55-62.

Goldberg ED. 1963. The oceans as a chemical system. In: Hill MN (ed). The composition of Seawater: Comparative and descriptive oceanography. The Sea: Ideas and Observations on Progress in the Study of the Seas 2: 3-25. Interscience Publisher, New York.

Gong H, DH Jiang, DV Lightner, C Collins & D Brock. 2004. A dietary approach to improve the osmoregulatory capacity of *Litopenaeus vannamei* cultured in the Arizona desert. Aquaculture Nutrition 10: 227-236.

Gross A, S Abutbul & D Zilberg. 2004. Acute and chronic effects of nitrite on white shrimp, *Litopenaeus vannamei*, cultured in low-salinity brackish water. Journal of the World Aquaculture Society 35(3): 315-321.

Gullian M, C Aramburu, B Sanders & R Lope. 2010. Viability of culturing pink shrimp *Farfantepenaeus duorarum* in low-salinity groundwater from the Yucatan Peninsula (SE Mexico). Aquaculture 302: 202-207.

Hernández M, LF Buckle, E Palacios & B Baron. 2006. Preferential behavior of white shrimp *Litopenaeus vannamei* (Boone 1931) by progressive temperature salinity simultaneus interaction. Journal of Thermal Biology 31: 565-572.

Mantel LH & LL Farmer. 1983. Osmotic and ionic regulation. In: Mantel LH (ed). Internal anatomy and physiological regulation. The Biology of Crustacea 5: 54-162. Academic Press, New York.

McGraw WJ & J Scarpa. 2004. Mortality of freshwater-acclimated *Litopenaeus vannamei* associated with acclimation rate, habituation period, and ionic challenge. Aquaculture 236: 285-296.

McNevin AA, CE Boyd, O Silapajarn & K Silapajarn. 2004. Ionic supplementation of pond waters for inland culture of marine shrimp. Journal of the World Aquaculture Society 35(4): 460-467.

Menz A & BF Blake. 1980. Experiments on the growth of *Penaeus vannamei* Boone. Journal of Experimental Marine Biology and Ecology 48: 99-111.

Murphy BR, D Willis & TA Springer. 1991. The relative weight index in fisheries management. Status and Need Fisheries 16: 30-48.

Nunes AJP & CV Lopez. 2001. Low-salinity, inland shrimp culture in Brazil and Ecuador -economics, disease issues move farms away from coasts. Global Aquaculture Advocate 4: 62-64

Parado-Estepa F, RP Ferraris, JM Ladja & EG de Jesus. 1987. Responses of intermolt *Penaeus indicus* to large fluctuations in environmental salinity. Aquaculture 64: 175-184.

Pauly D. 1984. Fish population dynamics in tropical waters: a manual for the use with programmable calculators. ICLARM, Studies and Reviews 8: 1-325. International Center for Living Aquatic Resources Management, Manila.

Pequeux A. 1995. Osmotic regulation in crustaceans. Journal of Crustacean Biology 15: 1-60.

Perez-Velazquez M, DA Davis, LA Roy & ML González-Félix. 2012. Effects of water temperature and Na+:K+ ratio on physiological and production parameters of *Litopenaeus vannamei* reared in low salinity water. Aquaculture 342/343: 13-17.

Ponce-Palafox J, CA Martínez-Palacios & LG Ross. 1997. The effects of salinity and temperature on the growth and survival rates of juvenile white shrimp *Penaeus vannamei* Boone 1931. Aquaculture 157: 107-115.

Ricker WE. 1979. Growth rates and models. In: Hoar WS, DJ Randall & JR Brett (eds). Bioenergetics and growth. Fish Physiology 7: 677-743. Academic Press, New York.

Roy LA. 2006. Physiological and nutritional requirements for the culture of the Pacific white shrimp, *Litopenaeus vannamei*, in low salinity water. PhD Dissertation, Graduate Faculty of Auburn University, Alabama, 126 pp.

Roy LA, DA Davis, IP Saoud & RP Henry. 2007. Effects of varying levels of aqueous potassium and magnesium on survival, growth, and respiration of the Pacific white shrimp, *Litopenaeus vannamei*, reared in low salinity waters. Aquaculture 262: 461-469.

Roy LA, DA Davis, IP Saoud, CA Boyd, HJ Pine & CE Boyd. **2010**. Shrimp culture in inland low salinity waters. Reviews in Aquaculture 2: 191-208.

Samocha TM, L Hamper, CR Emberson, AD Davis, D McIntosh, AL Lawrence & PM Van Wyk. 2004. Production of the pacific white shrimp, *Litopenaeus vannamei*, in high-density greenhouse-enclosed raceways using low salinity groundwater. Journal of Applied Aquaculture 15: 1-19.

Saoud IP, DA Davis & DB Rouse. 2003. Suitability studies of inland well waters for *Litopenaeus vannamei* culture. Aquaculture 217: 373-383.

Tsuzuki MY, RO Cavalli & A Bianchini. 2000. The effects of temperature, age and acclimation to salinity on the survival of *Farfantepenaeus paulensis* postlarvae. Journal of the World Aquaculture Society 31: 459-468.

Wang JQ, D Dong, S Wang & X Tian. 1998. Experimental studies on polyculture in closed shrimp ponds. I. Intensive polyculture of Chinese shrimp (*Penaeus chinensis*) with tilapia hybrids. Aquaculture 163: 11-27.

Wootton RJ. 1992. Fish ecology: tertiary level biology, 212 pp. Blackie, London.

Wyban JA & JN Sweeney. 1989. Intensive shrimp growout trials in a round pond. Aquaculture 76: 215-225.

Zhu C, SL Dong, F Wang & G Huang. 2004. Effects of Na/K ratio in seawater on growth and energy budget of juvenile *Litopenaeus vannamei*. Aquaculture 234: 485-496.

Zhu C, SL Dong & F Wang. 2006. The interaction of salinity and Na/K ratio in seawater on growth, nutrient retention and food conversion of juvenile *Litopenaeus vannamei*. Journal of Shellfish Research 25: 107-112.