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# 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

Luke A. Roy [a], D. Allen Davis [a,*], I. Patrick Saoud [b], Raymond P. Henry [c]

[a] *Department of Fisheries and Allied Aquacultures, 203 Swingle Hall, Auburn University, Alabama 36849-5419, USA*
[b] *Department of Biology, American University of Beirut, Beirut, Lebanon*
[c] *Department of Biological Sciences, 101 Life Science Building, Auburn University, Alabama 36849, USA*

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**Abstract**

Inland shrimp culture is being practiced in several regions of the United States. In Alabama, the culture of shrimp (*Litopenaeus vannamei*) in inland low salinity well water (approximately 4.0 ppt) faces several challenges. The ionic composition of these waters is deficient in several key minerals, including potassium ($K^+$) and magnesium ($Mg^{2+}$). The objective of the present study was to evaluate the effects of several aqueous $K^+$ and $Mg^{2+}$ concentrations on survival, growth, and respiration in juvenile *L. vannamei*. Two experiments, a 14-day trial with postlarvae and a 7-week trial with juvenile (~0.2 g) shrimp were conducted to evaluate effects of $K^+$ supplementation to culture water. Four different levels of $K^+$ (5, 10, 20, and 40 mg $l^{-1}$) were utilized and a treatment of 4 ppt reconstituted seawater was used as a reference for comparison to ideal ionic ratios. Additionally, a 6-week growth trial (~1 g juvenile shrimp) was performed to evaluate the effects of five concentrations of $Mg^{2+}$ (10, 20, 40, 80, 160 mg $l^{-1}$). Following completion of growth trials, measurements of basal respirometry rates were conducted to assess stress. Results from the 7-week $K^+$ growth trial indicated significant differences ($P<0.05$) in survival and growth among treatments. Individual weight, specific growth rate, and percent weight gain appeared to increase with increasing $K^+$ concentration (decreasing Na:K ratios). Results from the $Mg^{2+}$ experiment reveal a significant difference in survival between the lowest $Mg^{2+}$ treatment (60%) and all other experimental treatments (90–97%). However, no differences in growth were observed. Shrimp respiration in the lowest $Mg^{2+}$ treatment (10 mg $l^{-1}$) was significantly higher than in the 80 mg $l^{-1}$ treatment. These results suggest a potentially higher energetic cost associated with depressed aqueous $Mg^{2+}$ concentrations that are common in low salinity environments.


*Keywords:* Low salinity; Pacific white shrimp; Respiration; Potassium; Magnesium

## 1. Introduction

The inland culture of shrimp, particularly the Pacific white shrimp, *Litopenaeus vannamei*, is becoming more widespread in the Western hemisphere. Depending on their source, inland waters available for shrimp culture are usually of different salinities and possess different ionic compositions (Boyd and Thunjai, 2003). The ability of *L. vannamei* to tolerate a wide range of salinities (0.5–40 ppt) has made it a popular species for low salinity culture (McGraw et al., 2002; Samocha et al., 1998, 2002). Despite the relative success of some farmers in culturing *L. vannamei* in inland low salinity waters,

* Corresponding author. Tel.: +1 334 844 9312; fax: +1 334 844 9208.
*E-mail address:* ddavis@acesag.auburn.edu (D.A. Davis).

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problems still arise from deficiencies in the ionic profiles of pond waters (Saoud et al., 2003; Atwood et al., 2003). The lack of a necessary mix of essential ions, including potassium ($K^+$) and magnesium ($Mg^{2+}$), has been demonstrated to limit growth and survival of shrimp (Saoud et al., 2003; Davis et al., 2005).

Alabama has several saltwater aquifers (Feth, 1970) that are being utilized as sources of low salinity water for aquaculture (Saoud et al., 2003). Farmers in west Alabama have been successful in raising *L. vannamei* in inland low salinity waters by raising the $K^+$ and $Mg^{2+}$ levels of their pond waters to correct ionic ratio imbalances (McNevin et al., 2004). McNevin et al. (2004) observed increased shrimp production in Alabama low salinity waters (2–4 ppt) by raising the levels of $K^+$ (6.2 mg $l^{-1}$) and $Mg^{2+}$ (4.6 mg $l^{-1}$) to 40 mg $l^{-1}$ and 20 mg $l^{-1}$ using muriate of potash and potassium–magnesium sulfate, respectively. Furthermore, various studies have demonstrated a benefit to having appropriate levels or ratios of $K^+$ and $Mg^{2+}$ as well as other minerals during postlarval acclimation to low salinity waters (McGraw et al., 2002; McGraw and Scarpa, 2003; Saoud et al., 2003; Davis et al., 2005).

Both $K^+$ and $Mg^{2+}$ are ions essential for normal growth, survival, and osmoregulatory function of crustaceans (Mantel and Farmer, 1983; Pequeux, 1995). Potassium is the primary intracellular cation and is also important in the activation of the $Na^+$-$K^+$-ATPase (Mantel and Farmer, 1983), which is a key component of extracellular volume regulation. The lack of adequate levels of aqueous $K^+$ could thus be potentially detrimental in terms of the ability to effectively osmoregulate, because enzyme activity can be directly related to $K^+$ concentration (Bursey and Lane, 1971). In penaeid shrimp, hemolymph $K^+$ is regulated within a narrow range despite decreases in external salinity of the medium (Dall and Smith, 1981). Closely linked to the function of the $Na^+$-$K^+$-ATPase is adequate availability of $Mg^{2+}$, which serves as a cofactor (Mantel and Farmer, 1983; Furriel et al., 2000). The lack of adequate $Mg^{2+}$ or $K^+$ can affect $Na^+$-$K^+$-ATPase activity in crustaceans (Mantel and Farmer, 1983; Pequeux, 1995; Furriel et al., 2000). Magnesium also plays a role in the normal metabolism of lipids, proteins, and carbohydrates serving as a cofactor in a large number of enzymatic and metabolic reactions (Davis and Lawrence, 1997).

It is also well known that oxygen consumption can be affected by variations in environmental factors such as salinity, diet, activity level, temperature, and body weight (Mantel and Farmer, 1983; Brett, 1987). The impact of salinity on penaeid shrimp physiology has been examined by various authors such as Villareal et al. (1994) and Spanopoulos-Hernández et al. (2005). Less studied, however, is the impact of various ionic profiles of iso-saline inland low salinity well water on shrimp respiration. Consequently, the objective of the present study was to evaluate survival, growth, and respiration of *L. vannamei* maintained in artificial low salinity waters with different concentrations of $K^+$ and $Mg^{2+}$.

Table 1
Mean water quality parameters for growth trials with juvenile *L. vannamei* reared in low salinity waters

| Parameter | 14-day $K^+$ trial | $K^+$ growth trial | $Mg^{2+}$ growth trial |
|---|---|---|---|
| Dissolved $O_2$ (mg $l^{-1}$) | 7.98±0.04 | 7.24±0.05 | 7.3±0.13 |
| Temperature (°C) | 25.2±0.07 | 27.3±0.1 | 27.0±0.1 |
| Salinity (ppt) | 4.2±0.02 | 4.1±0.05 | 4.1±0.06 |
| pH | 8.1±0.0 | 8.0±0.02 | 8.1±0.03 |
| TAN[a] (mg $l^{-1}$) | 0.08±0.01 | 0.09±0.04 | 0.03±0.01 |
| $NO_2$ (mg $l^{-1}$) | 0.54±0.1 | 0.06±0.04 | 0.04±0.01 |

Values represent the mean±standard deviation.
[a] Total ammonia nitrogen.

## 2. Materials and methods

### 2.1. Culture conditions

The following study was conducted at the North Auburn Fisheries Research Station in Auburn, Alabama. Postlarval *L. vannamei* were obtained from Harlingen Shrimp Farms (Los Fresnos, TX, USA). Postlarvae (PL) were acclimated from 20 ppt to low salinity water (4.0 ppt) over a period of 8 h and maintained in a 220-l polyethylene nursery tank connected to a biological filter. During the first week, PL were maintained on a combination of Artemia nauplii (100 nauplii per shrimp) and a daily ration of commercial feed, PL Redi-Reserve (Ziegler Bros. Gardner, Pennsylvania, USA) at 25–50% body weight. Thereafter, shrimp were offered a commercial feed (Rangen 35% protein, Buhl, Idaho) and reared in the nursery system until they were of appropriate size for commencement of growth trials.

The experiment was conducted in twenty, 150-l polyethylene tanks. Each experiment consisted of five treatments with four replicate tanks per treatment. Individual tanks were equipped with an airlift biofilter, submerged air diffuser, and submersible heater to maintain an adequate temperature (27±0.5 °C). Shrimp were offered a commercial feed (Rangen 35% protein) four times daily using an automatic feeder. Light control was set at 16 h day and 8 h night. Dissolved oxygen (DO), pH, salinity, and temperature were measured daily whereas ammonia nitrogen and nitrite nitrogen were measured twice weekly according to Solorzano (1969) and Parsons et al. (1985), respectively (Table 1).