Effects of Dietary Calcium and Substrate on Growth and Survival of Juvenile Queen Conch (*Strombus gigas*) Cultured for Stock Enhancement

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ABSTRACT

The queen conch, *Strombus gigas*, is one of the most valuable fisheries species throughout the Caribbean, however, the populations have been declining for several decades. Research focused on aquaculture, restocking, and transplanting techniques is being conducted to help replenish wild conch populations. A 38 week experiment to determine the influence of diet and substrate on queen conch growth and survival began at Harbor Branch Oceanographic Institution, Ft. Pierce, Florida in December 2003. Hatchery-reared juvenile queen conch (32.3 ± 2.4 mm shell length) were stocked into six individual recirculating systems at 75 conch/m^2. There were three treatments, with two replicates per treatment: 1) aragonite sand substrate with 1x calcium feed, 2) aragonite sand substrate with 2x calcium feed, and 3) silicate substrate with 1x calcium feed. Calcium, alkalinity, and pH were measured once per week; and conch length and weight measurements were taken on a biweekly or monthly basis. Results indicate that there is no difference in the growth rate with additional dietary calcium, the 2x feed (0.07 ± 0.01 mm/d) compared to the 1x feed (0.08 ± 0.01 mm/d). However, there appears to be a slower growth rate in those animals stocked on the silicate substrate (0.04 ± 0.02 mm/d) in comparison to the conch grown on aragonite sand substrate (0.07 ± 0.01 mm/d). Calcium and alkalinity levels remained the same in all treatments. Conch grown on the silicate substrate had a significantly higher mortality (57%) than the 1X and 2x treatment on aragonite (18.7% and 25.8%, respectively). These results can be used to assist in choosing the husbandry techniques best suited to culture queen conch juveniles for stock enhancement purposes.

KEY WORDS: Aquaculture, conch, *Strombus*

Efectos de Dietéticos de Calcio y del Substrato en Crecimiento y Fuerza de la Cáscara del Conch Juvenil de la Reina (*Strombus gigas*), Crecido en un Criadero

El caracol, *Strombus gigas,* es uno de la especie más valiosa de las industrias pesqueras a través del Caribe. Sin embargo, puesto que las poblaciones han estado declinando por varias décadas. Mucha de los focos actuales de la investigación en la acuacultura, volviendo a surtir, y técnicas de trasplante a ayudar a llenar las poblaciones salvajes del caracol. De acuerdo con un experimento conducido sobre un año para determinar la influencia de la dieta y del substrato en fuerza, morfología y crecimiento de la cáscara del conch de la reina comenzó en Harbor Branch Oceanographic Institution, en Ft. Pierce, la Florida, en Diciembre de 2003. La juvenil del caracol crecido en un criadero (32.3 ± 2.4 mm de la cascara) fueron almacenados en seis sistemas que recirculaban individuales en 75 conch/m^2. Hay tres tratamientos, con dos réplicas por el tratamiento: 1) substrato de la arena del aragonite con la alimentación del calcio 1x, 2) substrato de la arena del aragonite con la alimentación del calcio 2x, y 3) substrato del silicato con la alimentación del calcio 1x. El calcio, la alcalinidad, y el pH se miden una vez por semana; y las medidas de la longitud y del peso del conch se adquieren bisemanal o base mensual. Los resultados indican que no hay diferencia en la tarifa de crecimiento con calcio dietético adicional, la alimentación 2x (0.07 ± 0.01 mm/d) comparado a la alimentación 1x (0.08 ± 0.01 mm/d). Sin embargo, aparece ser una tarifa de crecimiento más lenta en esos animales almacenados en el substrato del silicato (0.04 ± 0.02 mm/d) en la comparación al substrato de la arena del aragonite (0.07 ± 0.01 mm/d). Los niveles del calcio y de la alcalinidad han seguido en todos los tratamientos. Las caracols en el substrato del silicato tiene mas mortalito (57%) entonces a la control y la alimentación 2x (18.7% y 25.8%). Estos resultados se pueden utilizar para asistir a los métodos usados para cultivar a juveniles del concha de la reina para los propósitos comunes del realce.

PALABRAS CLAVES: Aquacultura, concha, *Strombus*

INTRODUCTION

The queen conch, *Strombus gigas*, is one of the most valuable fisheries species throughout the Caribbean, however, the populations have been declining for several decades. Research focused on aquaculture, restocking, and transplanting techniques is being conducted to help replenish wild conch populations (Creswell 1984, Davis and Dalton 1991, Stoner and Glazer 1998, Pardee Woodring and Boettcher 2001, Delgado et al. 2002, Shawl and Davis 2004, Davis and Shawl 2005). Determining ideal husbandry techniques for juvenile conch reared for stock enhancement purposes will ensure that hatchery-reared conch released in the wild will have a similar survival rates as their wild counterparts. Knowing optimal stocking density, substrate, water quality, diets, and systems will assist in growing conch with the shell strength and morphology equal to wild conch. Previous studies have indicated that hatchery-reared conch are more susceptible to predators due to a thinner shells and smaller spines (Stoner 1994, Stoner and Davis 1994). Hatchery-reared conch that are stocked at higher densities, tend to have lower growth rates, smaller shells, and shorter spires (Laughlin and Weil 1983, Appledoorn and Sanders 1984, Creswell 1984, Weil and Laughlin 1984, Spring and Davis 2003). However, conch grown at high densities on a calcium-based substrate tend to have a stronger shell than those conch grown with the same conditions at low densities (Spring 2003).

Culture methods, including stocking density, for grow out of queen conch are well known. Therefore, this study investigates the effect of dietary calcium and calcium substrate on growth and survival of juvenile queen conch. These results can be used to understand ideal culture techniques that will enhance the survival rate of restocked conch.

MATERIALS AND METHODS

This experiment was conducted at Harbor Branch Oceanographic Institution (HBOI) in Ft. Pierce, FL from December 17, 2003 to September 1, 2004 (38 weeks). Six individual recirculating systems located inside a shaded greenhouse were constructed of a fiberglass trough (2.5 m x 0.5 m x), a 94 L polyethlyene sump (0.6 m x 0.5 m x 0.4 m), and a 1/30 HP Little Giant™ magnetic drive pump. Each system had a raised substrate with water entering both above and below the substrate (Shawl and Davis 2004). Aeration was added to all tanks. Every two weeks, the systems were drained completely for cleaning. There was no incoming water; however, water was added to the sumps twice per week to account for evaporation. The same amount of water was added to all six systems.

Three treatments were examined with two replicates each:

i) Aragonite sand substrate and 1x calcium diet,
ii) Aragonite substrate and 2x calcium diet, and
iii) Silicate substrate and 1x calcium diet.

The silicate substrate was chosen as a non-calcium based substrate to test for the effects of substrate on growth and survival. The 1x calcium diet was the standard diet used at HBOI to grow conch. The 1x calcium diet was made of dried *Ulva sp.*, catfish chow, calcium palmitate, and an alginate based binder. The 2x diet consisted of dried *Ulva sp.*, catfish chow, alginate, and twice the amount of calcium palmitate. The Harbor Branch Environmental Laboratories, Inc. tested several samples of the 2x diet and compared the results to the 1x diet to confirm that twice the amount of calcium was present. Initial feeding rate was 0.15g/conch/day, but was adjusted accordingly so that the animals were fed to satiation (0.40 g/conch/day). All treatments received the same amount of feed throughout the experiment.

Each replicate was stocked with 99 juvenile queen conch (at 75 conch/m^2). The hatchery-reared queen conch were cultured at the Caicos Conch Farm, Turks and Caicos Islands, BWI and were purchased from Oceans, Reefs and Aquariums in Ft. Pierce, FL. Initial length (mm) and weight (g) was measured for all conch prior to stocking. For each replicate, 20 animals (20%) were randomly chosen to be the permanent sampling group. A portion of the apex of the shell was painted with a non-water based acrylic paint to distinguish the group. Mortalities were recorded and immediately replaced with another conch to maintain density. These replacements were marked and were not included in any measurements. Length (mm) and weight (g) of the sample animals were taken twice per month for the first 29 weeks, and then once per month for the remainder of the experiment.

Water qualities were measured on a daily, weekly, or biweekly basis, and one sample from each replicate was taken. Temperature was taken daily, pH and salinity were measured once per week, and ammonia, nitrite, and nitrates were measured weekly or biweekly. Calcium and alkalinity were sampled twice per week for the first five weeks and then once per week for the remainder of the experiment. One sample from each replicate was used to measure water quality, and two samples per replicate were used to test calcium and alkalinity levels. On days when water was added to the sumps, a water sample for measuring calcium and alkalinity was taken before and after the addition.

A two way repeated measure ANOVA test was used to determine significant differences in the amount of calcium and alkalinity in the treatments. Due to the non-normal distribution of results for conch growth rate, wet weight gain rate, and percent survival, a non-parametric Kruskal-Wallace one way ANOVA on ranks was used.

RESULTS

The final shell length was 53.7 ± 0.6 mm for the aragonite 1x diet, 42.2 ± 3.1 for the silicate treatment, and 49.6 ± 3.5 for the aragonite 2x treatment. The daily growth rates were similar for conch grown on aragonite substrate fed the 1x and 2x diets (Figure 1). The conch fed the 1x diet grew 21.4 mm for an overall growth rate of 0.08 mm/d, and the conch fed the 2x diet had a growth rate of 0.07 mm/d (17.0 mm increase). Conch grown on the silicate substrate did not grow as well (9.6 mm), therefore, had a much lower growth rate (0.04 mm/d). However, there were no significant differences in growth rate between the three treatments ($p = 0.400$).

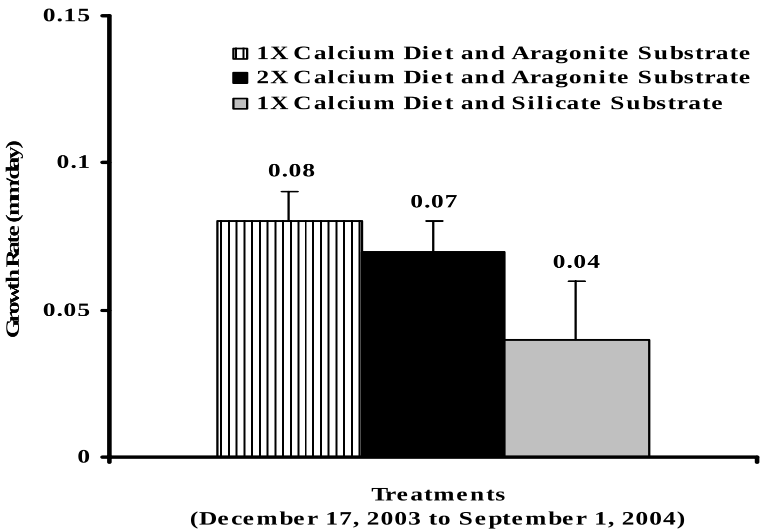

Figure 1. Overall growth rate (mm/d) for the three treatments (mean ± sd, n = 2).

The conch in the aragonite 1x diet treatment gained 12.9g of total wet weight, in comparison to 4.9 g and 10.3 g for conch grown on the silicate and fed the 2x diet, respectively. The final weight of the three treatments was 16.1 ± 0.2 for the aragonite 1x diet, 8.2 ± 2.9 for the silicate substrate, and 13.7 ± 2.3 for the animals fed the 2x diet. There was no significant difference in wet weight gain rate between all treatments ($p = 0.067$).

Water quality parameters remained relatively constant in all three treatments throughout the experiment (Table 1). There was a significant difference in the calcium levels between the 1x and 2x treatment ($p = 0.008$), and between the 2x treatment and silicate treatment ($p = 0.030$). However, there was no significant difference between the silicate treatment and the aragonite 1x treatment ($p = 0.107$). There was no significance difference for alkalinity levels in all three treatments ($p = 0.718$) (Table 2).

Table 1. Water quality for the experimental tanks from December 17, 2003 to September 1 , 2004. Results are expressed as mean ± sd and range. For each treatment the replicates were averaged and the expressed mean is the average of these replicate averages (n = sample times for each treatment).

	Aragonite Substrate 1X Calcium Diet	**Silicate Substrate 1X Calcium Diet**	**Aragonite Substrate 2X Calcium Diet**
Temp (°C)	27.2 ± 1.5 (520)	27.1 ± 1.6 (520)	26.9 ± 1.5 (520)
	19.1 - 31.0 (520)	18.4 - 30.2 (520)	18.0 - 30.6 (520)
Salinity (ppt)	33.6 ± 2.0 (112)	33.6 ± 2.1 (112)	33.9 ± 2.3 (112)
	29 - 37 (112)	29 - 37 (112)	29 - 38 (112)
pH	8.6 ± 0.1 (112)	8.6 ± 0.2 (112)	8.7 ± 0.1 (112)
	8.0 - 8.8 (112)	7.7 - 8.8 (112)	8.3 - 8.9 (112)
Ammonia (mg/L)	0.26 ± 0.61 (52)	0.29 ± 0.61 (52)	0.10 ± 0.37 (52)
	0 - 1.9 (52)	0 - 1.8 (52)	0 - 1.8 (52)
Nitrate (mg/L)	3.15 ± 0.70 (50)	3.00 ± 0.67 (50)	2.94 ± 0.68 (50)
	2 - 5 (50)	1 - 4 (50)	1 - 5 (50)
Nitrite (mg/L)	0.04 ± 0.02 (50)	0.05 ± 0.04 (50)	0.03 ± 0.02 (50)
	0 - 0.10 (50)	0 - 0.32 (50)	0 - 0.17 (50)

Table 2. Calcium and alkalinity measurements for the three treatments December 17, 2003 - September 1, 2004. Results are expressed as mean ± sd and range. For each treatment the replicates were averaged and the expressed mean is the average of these replicate averages (n = sample times for each treatment).

	Aragonite Substrate 1X Calcium Diet	Silicate Substrate 1X Calcium Diet	Aragonite Substrate 2X Calcium Diet
Calcium (mg/L)	426 ± 35.6 (86)	440 ± 54.5 (86)	456 ± 63.2 (86)
	345 - 513 (86)	218 - 547 (86)	270 - 582 (86)
Alkalinity (mg/L as $CaCO_3$)	114 ± 17.3 (86)	110 ± 17.1 (86)	120 ± 16.6 (86)
	75 - 162 (86)	55 - 168 (86)	90 - 177 (86)

Conch grown on the silicate substrate had a higher mortality (57% ± 39%, n = 2) than the 1x and 2x treatments (18.7% ± 4%, n = 2 and 25.8% ± 14%, n = 2, respectively), however, there was no significant difference in the final mortality levels in all three treatments (p = 0.067) (Figure 2). It also appeared that the conch on the silicate substrate did not feed as well and were less active. The feed conversion ratios (FCR) were fairly similar for the 1x and the 2x treatment (1.5 and 1.9, respectively). The FCR for the silicate treatment was higher (4.0), indicating slow growth and high mortality.

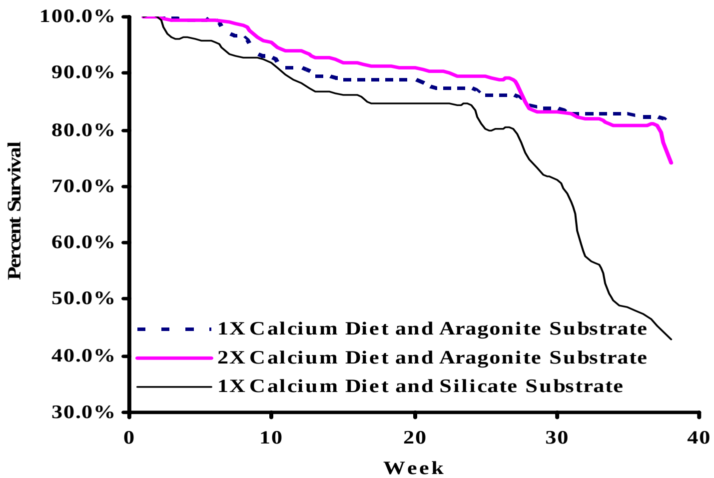

Figure 2. Average percent survival for the three treatments December 17, 2003 – September 1, 2004 (n = 2).

DISCUSSION

Substrate, stocking density, diet, and water quality are important factors for the successful aquaculture of queen conch. The animals raised on the non-calcium based silicate substrate had a much slower growth rate and higher mortality. However, the amount of calcium in the water available to the conch did not differ from the other treatments. Even though the silicate substrate was rinsed thoroughly and was similar in grain size as the aragonite, it is possible that these animals were stressed and unwilling to feed due to a characteristic of the silicate. Previous studies have shown slower growth rates on substrates other than sand (Appeldoorn and Sanders 1984, Laughlin and Weil 1983).

There appeared to be little effect on growth rate with additional dietary calcium. Although there have not been any studies of this kind on Strombidae conch, there has been similar research conducted on terrestrial land snails. Studies have found a proportional increase in growth rate with increasing dietary calcium for *Acatina fulica* (Ireland 1991). However, the increased growth rate in *A. fulica* appeared to be directly correlated to food consumption (Ireland 1991).

The conch fed the 1x diet gained more weight overall, than the conch fed the 2x diet. This is contrary to the findings with *A. fulica* in which the snails fed a higher concentration of calcium, had a higher shell weight and greater shell thickness (Ireland 1991). Based on these results, it is recommended that conch be grown on an aragonite substrate and are fed the standard 1x calcium diet. It appears to be unnecessary for culturist to purchase excess calcium for the juvenile feed. However, the shells will be further analyzed using a Comten Industries digital force system, to determine if there are differences in shell strength between treatments when additional calcium is added to the diet.

In order for a restocking program to be successful, scientists must be able to produce a juvenile queen conch equal in shell strength to its wild counterparts to aid the conch in survival against shell crushing predators. Future research involving supplemental dietary calcium and aragonite substrate will aid in defining restocking guidelines.

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