

Removal of suspended solids from the effluents of a shrimp farm by the Blood Ark *Anadara tuberculosa* (Sowerby, 1833)

Remoción de sólidos suspendidos en los efluentes de una granja camaronera por la almeja pata de mula *Anadara tuberculosa* (Sowerby, 1833)

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ABSTRACT

The potential of *Anadara tuberculosa* for bioremediation of shrimp farm effluents was evaluated in five field experiments performed in a semi-intensive shrimp farm in Sonora (NW Mexico), and yielded mean filtration, clearance and biodeposition rates of 33.10 mg/h/g, 0.41 L/h/g and 31.19 mg/h/g, respectively. This study demonstrates that *A. tuberculosa* adults can remove the particulate matter of a semi-intensive shrimp farms effluents.

Key words: *Anadara tuberculosa*, shrimp farm effluents, bioremediation, filtration, clearance.

RESUMEN

Se realizaron cinco experimentos en una granja de cultivo semi-intensivo de camarón ubicada en Sonora (Noroeste de México) con el fin de verificar *in situ* el potencial de *Anadara tuberculosa* para la biorremediación de los efluentes de granjas camaroneras. Se obtuvieron tasas medias de filtración y de clarificación de 33.10 mg/h/g y 0.41 L/h/g y la de biodepositación fue 31.19 mg/h/g. Este estudio demuestra que individuos adultos de *A. tuberculosa* pueden remover la materia particulada de los efluentes de las granjas camaroneras semi-intensivas.

Palabras clave: *Anadara tuberculosa*, efluentes camaronícolas, biorremediación, filtración, clareo.

The effluents of land-based aquaculture may become a significant source of eutrophication in coastal ecosystems. This negative impact could be minimized by growing filter-feeding bivalves in the drainage ditches, which could be marketed at the end of the growing cycle to offset the increase in operating costs (Lin *et al.*, 1993; Jones & Preston, 1999). In view of the harsh environmental conditions of NW Mexico because of its hot, dry climate, this would be better achieved with a local species but, since there is little information on the biological characteristics of native bivalves (Massó-Rojas *et al.*, 1996), their potential for bioremediation is unknown. The blood ark *Anadara tuberculosa* (Sowerby, 1833) lives on the soft bottoms of local mangrove swamps. In this study we measured its filtration, clearance and biodeposition rates, and recorded its mortality and growth during different stages of the production cycle of a semi-intensive shrimp farm.

The Chomojabiri shrimp farm (southern Sonora State: 26° 42.312' to 26° 42.615' N and 109° 37.596' to 109° 37.858' W) has nine ponds (23 ha) stocked with 20 postlarvae/m². Specimens of *A. tuberculosa* of similar size (height = 3.0-3.5 cm), were collected in the nearby lagoon of Agiabampo and placed in the drainage ditch. Filtration experiments were performed at different stages of the production cycle (day 1: shrimp stocking; day 29: 2-3%

water exchange; day 49: 10% water exchange; day 123: partial harvest, 20% water exchange; day 188: final harvest, drainage of 50% of the pond water).

In each experiment, four specimens were placed in individual 2 L plastic chambers which received water pumped from the drainage ditch with a constant flow of 3 L/h. Two chambers with one empty shell served as controls. Water temperature, oxygen concentrations and salinity were monitored every hour with an YSI dissolved oxygen meter and an Atago refractometer. Water samples, obtained at 4 h intervals from 12:00 to 08:00 hours from the inflow and outflow of each chamber, were used to evaluate the concentration of total and organic suspended solids (TSS and OSS). The biodeposits (faeces and pseudofaeces) were collected as soon as noticed in each chamber. These samples were concentrated on Whatman GF-C glass fiber filters, washed with 10 mL of 3% ammonium formate, dried at 105 °C to constant weight and ashed during 8 h at 475 °C in a muffle furnace. The organic contents of TSS and biodeposits were calculated by difference.

The standardized mass of particles retained (filtration rate: FR, mg/h/g), corrected according to the mass of sediments settled in the control chambers, was calculated according to Hawkins *et al.* (1998): $FR = (IMb/t) \times (TSS/ISS)$. The clearance and biodeposition rates (CR, L/h/g and BR, mg/h/g) were calculated according to Lefebvre *et al.* (2000): $CR = (IMb/t)/ISS$ and $BR = B/t$; where IMb = inorganic matter (mg) in the faeces and pseudofaeces, t = incubation time (h), ISS = inorganic suspended solids (mg) in the effluents, B = total dry mass (mg) of the biodeposits.

The mean values of FR and CR determined in the five sets of experiments were compared using one-way block analysis of variance, and the different means were separated with Tukey's tests (Zar, 1996).

The water characteristics of the effluent varied widely throughout the growth cycle; during the first two months the daily water exchanges were 0 to 5% and salinity was high because of high evaporation, but it decreased in the second part of the cycle when the exchange rates were increased to 10-20%. Water temperature was low at the beginning and at the end of the shrimp farming period and TSS increased from the first to the fourth

experiment, probably because of sediment resuspension due to the increased water exchange rates and to other pond handling activities. This was especially evident on day 123, which coincided with the operations of partial harvest. The organic content of TSS varied from 35.1 to 48.1%, and the highest value was measured during experiment 3 (Table 1).

The first and the fourth experiments gave the highest FR values, because of the high CR in the first case and of the high TSS concentration in the second. There was no difference in CR between the second and the fourth experiment, but the respective FR were different because of the difference in TSS concentrations. The lowest CR of the last experiment coincided with the highest TSS concentration (Tables 1 and 2).

Considering the organic content of TSS of each experiment, the amount of OSS removed ranged from 6.95 ± 2.20 to 22.12 ± 3.46 mg/h/g and was significantly correlated with FR ($r = 0.970$; $p < 0.05$).

The mass of biodeposits (faeces and pseudofaeces) ranged between 88.4 and 94.5% of the total solids retained by filtration (Table 2) and there was a close relationship between FR and BR ($r = 0.9995$; $p < 0.0001$).

The characteristics of the effluent were similar to those of other farms of NW Mexico (Páez-Osuna *et al.*, 1997, Hernández-Ibarra, 1999) and were within the known vital ranges of *Anadara tuberculosa* and other *Anadara* species, which tolerate lengthy anoxic events (Bayne, 1973) and temperatures in the range 26 to 35 °C (Borrero, 1986). Mean TSS concentration was high (91.16 mg/L) but several species of *Anadara* tolerate turbid environments, since they live on soft substrates where suspended solids may be even higher (Broom, 1985). Therefore, except for the effluent salinity that exceeded the upper limit of 40‰ reported by Baqueiro (1980), the water characteristics of the effluent were within the known tolerance limits of *A. tuberculosa*.

There is little and contrasting information on the filtration and clearance rates of commercial-size *Anadara* spp. In this study, the highest CR and FR were 0.88 L/h/g and 56.54 mg/h/g, which are one order of magnitude higher than the ranges of 0.02-0.05 L/h/g and 0.9-2.4 mg/h/g found under laboratory conditions

Table 1. Mean effluent characteristics during the filtration experiments. Values are means \pm SD of six samples (4-h interval).

Day	Oxygen (mg L ⁻¹)	Salinity (‰)	Temperature (°C)	TSS (mg L ⁻¹)	OSS (mg L ⁻¹)
1	6.2 \pm 0.56	41.0 \pm 0.60	26.2 \pm 2.13	59.2 \pm 10.0	25.3 \pm 3.5
29	5.7 \pm 1.30	50.0 \pm 0.30	30.7 \pm 0.62	59.0 \pm 13.1	22.5 \pm 4.7
49	5.8 \pm 1.04	49.0 \pm 0.90	30.6 \pm 1.80	72.8 \pm 10.1	35.0 \pm 4.2
123	5.6 \pm 2.06	40.0 \pm 0.30	31.0 \pm 1.64	156.5 \pm 16.4	55.2 \pm 5.9
188	6.9 \pm 1.47	41.0 \pm 0.40	21.8 \pm 1.90	108.3 \pm 27.9	48.0 \pm 5.7

Table 2. Mean (\pm SD) of the filtration (FR), clearance (CR) and biodeposition rates (BR) of *A. tuberculosa* measured in situ experiments. Different letters indicate significant differences between daily sets of experiments (one way block analysis of variance, $\alpha = 0.05$) $a < b$. (BR/FR): biodeposition as percentage of TSS filtered.

Experiment	FR ($\text{mg}\cdot\text{h}^{-1}\cdot\text{g}^{-1}$)	CR ($\text{L}\cdot\text{h}^{-1}\cdot\text{g}^{-1}$)	BR ($\text{mg}\cdot\text{h}^{-1}\cdot\text{g}^{-1}$)	(BR/FR) (%)
1	51.59 \pm 10.70 _b	0.88 \pm 0.15 _c	49.79 \pm 10.30	91.2
2	23.24 \pm 4.61 _a	0.40 \pm 0.10 _b	21.68 \pm 3.65	93.3
3	19.43 \pm 4.99 _a	0.27 \pm 0.07 _{ab}	17.18 \pm 4.59	88.4
4	56.54 \pm 14.54 _b	0.36 \pm 0.07 _b	53.42 \pm 12.30	94.5
5	14.72 \pm 6.45 _a	0.14 \pm 0.04 _a	13.89 \pm 5.54	94.4
Global means	33.10 \pm 19.45	0.41 \pm 0.28	31.19 \pm 18.88	92.4

by Peraza-Gómez (2005) and Partida-Arangure (2005), but lower than the CR of 1.14 to 2.62 L/h/g reported by Wong *et al.* (1997) in experiments with particle-free water. All these data are lower than the average values of 3.6 L/h/g and 320 mg/h/g measured with three different bivalve species by Hawkins *et al.* (1998). In addition, the mean individual organic dry weight of our experimental organisms ranged from 0.86 to 1.06 g/ind. Therefore, the individual CR measured in the first and fifth experiment would have been between 1.02 to 0.13 L/h/ind, which is between 28 and 3.6% of the 3.65 L/h/ind recalculated for raft-reared blue mussels using the data by Figueras (1989).

Hawkins *et al.* (1998) found a direct relationship between FR and BR, and calculated that the biodeposits are close to 93% of the solids retained, similar to the range of 90.4 to 97.1% reported for *Crassostrea gigas* (Thunberg, 1793) by García-Esquivel *et al.* (2004) and to the values of 88.4 to 94.5% measured in this study.

According to our data, *A. tuberculosa* may clear on average 0.4 L of effluent water in one hour, removing 33.10 mg and producing 31.92 mg of biodeposits. Therefore, assuming that its filtration and clearance are constant (Wong *et al.*, 1997) one organism with a tissue dry weight of 1 g (close to 4.5-5 cm in length) kept in conditions similar to those of this study, may retain 794 mg/day and produce 748 mg/d of biodeposits.

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