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Use of the Asian Clam (*Corbicula fluminea* Müller, 1774) as a Biomechanical Filter in Ornamental Fish Culture

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Abstract

This study aimed to determine whether the Asian clam (*Corbicula fluminea* Müller, 1774) can be used as a biomechanical filter in ornamental fish aquariums. Various densities of this freshwater mussel were maintained with goldfish (*Carassius auratus* L., 1758), and their filtration efficiency, tolerance to environmental stressors, and viability were examined over 75 days along with the growth of both the mussels and fish. The addition of mussels removed large amounts of total suspended solids from the water, improved the quality of the water, and led to enhanced growth and feed conversion efficiency of the goldfish. Furthermore, the polyculture of fish and mussels in the aquariums did not have any negative effects on the viability of either species.

Keywords: Gold fish, *Carassius auratus*, water quality, freshwater mussel, *Corbicula fluminea*.

Süs Balıkları Yetiştiriciliğinde Asya Midyesi (*Corbicula fluminea* Müller, 1774)'nin Biyomekanik Filtre Olarak Kullanılması

Özet

Bu çalışma Asya midyesi (*Corbicula fluminea* Müller, 1774)'nin süs balığı akvaryumlarında biyomekanik filter olarak kullanılabilirliğini belirlemek amacı ile yapılmıştır. Japon balıkları ile (*Carassius auratus* L., 1758) farklı oranlarda stoklanan tatlısu midyesinin, filtrasyon verimliliği, çevresel streslere karşı dayanıklılığı, midye ve balıkların büyümeleri, gelişmeleri ve yaşayabilirlikleri 75 gün boyunca incelenmiştir. Akvaryumlara midye ilavesi, sudan askıda katı maddeleri önemli düzeyde uzaklaştırmış, su kalitesindeki iyileşmeler japon balıklarının büyüme ve yem değerlendirme performansını olumlu etkilemiştir. Akvaryumlarda balık ve midye kombinasyonunun her iki türün yaşayabilirliklerine herhangi olumsuz bir etkisi olmamıştır.

Anahtar Kelimeler: Japon balığı *Carassius auratus*, su kalitesi, tatlı su midyesi *Corbicula fluminea*.

Introduction

The ornamental fish trade has been increasing at an average rate of 14% per annum since the mid-1980s. According to the Food and Agriculture Organization of the United Nations (FAO), this trade reached to US$ 1 billion in 2010 (FAO, 2010), with freshwater species representing 90% of this value (Morgan, 2010). The goldfish (*C. auratus* L., 1758) is one of the most popular and commercial species in the ornamental fish market (Yanar and Tekelioğlu, 1999). Goldfish do not experience feeding problems, and their diet includes aquatic plants, detritus, crustaceans, *Daphnia* spp., *Tubifex* spp., *Artemia* spp., and dry feed (Savaş *et al*., 2006).

Ornamental fish are raised in ponds, tanks, and aquariums. Where fish are stocked at a high density, water quality parameters can decrease due to the increased amount of feed. This can lead to the fish suffering from increased stress, which in turn, can result in reduced growth, increased exposure to diseases, and higher mortality rates, and thus lesser aquaculture production with lower stocks (Boyd and Tucker, 1998; McKenzie and Özbay, 2010). Mechanical filtration is often used in the cleaning systems of ponds, tanks, and aquariums to remove total suspended solids (TSS) and thus prevent the reduction in water quality parameters. However, this is economically quite expensive. In natural water bodies, this task is performed by filter feeders.

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Freshwater mussels play an important role in freshwater ecosystems. They remove organic detritus, bacteria, plankton, and other microscopic organisms via filtration (Borchard *et al*., 1986) and help maintain the quality of river and lake ecosystems (Hall and Carson, 2006). Freshwater mussels have been used as the most economical filtration method in recreational lakes to control algal problems (Shapiro and Wright, 1984), in waste water treatment ponds (Henderson and Wert, 1976; Weigmann, 1982; Henderson, 1983), and in aquaculture ponds/tanks (Cremer and Smitherman, 1980; Smith, 1985; Laws and Weisburd, 1990). The addition, bivalves has been proven to be an inexpensive method for removing suspended solids and dissolved nutrients and for controlling algal growth through suspension feeding in both marine and freshwater systems. Furthermore, their filtration of the water also transfers the nutrients from the water column into the sediments (McKenzie and Özbay, 2009). Thus, they are an ideal candidate for use as a biomechanical filter.

The Asian clam (*C. fluminea* Müller, 1774) is a small, freshwater bivalve mollusk that is native to the freshwaters of southeastern Asia, Europe, and North America. It has been reported that this species is widely distributed in the Tigris, the Orontes River, the Seyhan River, and the Ceyhan River systems. Asian clams are found in lakes and rivers that contain silt, mud, sand, and gravel substrates and can live in waters with temperatures between 2°C and 30°C. They usually prefer lotic (flowing water) habitats.

Early studies that were conducted to improve water quality and to clarify water used mollusks, such as the Asian clam and the zebra mussel (*Dreissena polymorpha*) (Buttner and Heidinger, 1981; Reeders *et al*., 1993); Asian clams are now commonly used to assess water quality parameters (Cossu *et al*., 1997; Doyette *et al*., 1997; Vidal *et al*., 2001).

Various studies have investigated the use of bivalve mollusks as a biomechanical filter in natural water bodies, aquaculture, and waste water treatment. For example, Mueller *et al*. (2004) previously examined the effects of the freshwater mussel *Elliptio complanata* and silver carp (*Hypophthalmichthys molitrix*) on water quality and plankton density in partitioned aquaculture systems housing growing catfish (*Ictalurus punctatus*), and McKenzie and Özbay (2010) examined the use of *E. complanata* as biomechanical filter in catfish ponds. Miranda *et al*. (2010) also investigated the effects of Pacific oyster (*Crassostrea gigas*) and tilapia culture on TSS, ammonia, and plankton density in a recirculation system.

However, no studies have assessed this use in ornamental fish culture. Therefore, in this study, we determined whether Asian clams can be used as a biomechanical filter in goldfish aquariums and their optimal density for efficient commercial ornamental fish production.

Materials and Methods

Study Species and Experimental Setup

Juvenile goldfish (initial weight, 1.98 g; length, 2.85 cm) and Asian clams (initial weight, 1.38 g; length, 1.41 cm) were obtained from a commercial ornamental fish farm (Delta Aquarium). All of the fish (n = 600) were quarantined and acclimated for 2 weeks in a 1000-L tank (100 × 100 × 100 cm) before the start of the experiment. Similarly, the mussels were acclimated for 2 weeks in a 375-L tank (150 × 50 × 50 cm) before the start of the experiment. Following acclimation, 225 of the fish were randomly assigned to 15 unit 128-L aquariums (80 × 40 × 40 cm) at a density of 15 fish per aquarium. Each aquarium contained an air-driven sponge filter that provided constant aeration. The aquariums were separated into five treatment groups that consisted of five different densities of mussels (0M, 8M, 16M, 24M, and 32M per aquarium), with three replicates per treatment. The experiment was conducted over 75 days.

The room in which the experiment was conducted contained a fluorescent light that was set to a 12-h light: 12-h dark cycle. Each experimental group was fed with commercial fish feed containing 28% crude protein three times a day (09:00, 12:00, and 17:00) by hand to visual satiation.

Goldfish and mussel weights were obtained using a Scaltec digital balance (precision = 0.01 g). Goldfish lengths were also measured with a measuring board (precision = 1 mm), whereas mussel lengths were measured with an INSIZE digital caliper (precision = 0.01 mm). A 200-W thermostatic heater was used to maintain the correct aquarium temperature.

Water Quality Measurements

Each day, approximately 20% of the water was changed using a time-adjusted automatic system. Measurements of water temperature (digital thermometer), dissolved oxygen (WTW 320i oximeter), and pH (WTW 315i pH meter) were made on a daily basis in each aquarium. In addition, the concentrations of ammonia, nitrite, nitrate, phosphate, and TSS were measured once every 15 days.

Chemical Analysis

The concentrations of ammonia, nitrite, nitrate, and phosphate were measured using a PG T80 UV-VIS Spectrophotometer. The concentration of TSS was determined by filtering 1000 ml of sample through a 0.45-µm glass fiber filter and then drying the filter in an oven at 105°C. The concentration of TSS was then calculated by subtracting the original weight of the filter from the dried weight of the filter, multiplying this by 1000, and then dividing by the volume of the sample (Boyd and Tucker, 1998; American Public Health Association, 2012).

Determination of Growth

All fish were weighed, counted, and had their total lengths measured at the beginning and the end of the feeding trial to calculate weight gain (WG), WG percentage (WGP), specific growth rate (SGR), feed conversion ratio (FCR), and survival rate (SR).

Average mussel growth (mm) = length x width (mm) was calculated

Statistical Analysis

Statistical analysis consisted of one-way ANOVA, using the probability level of 0.05. After ANOVA, significant differences among means were determined by Duncan's multiple range test. All statistical analyses were performed using SPSS 15.0 for Windows (SPSS INC. Chicago, IL, USA).

Results

The mean dissolved oxygen concentration across treatments ranged from 6.14 to 7.18 mg L^{-1}, the pH ranged from 8.4 to 8.6, and the water temperature ranged from 22.9°C to 23.3°C. There was no significant difference in any of the water quality variables between treatments ($P<0.05$). At the beginning of the experiment, the nitrogen and phosphate levels in tap water were measured, and nitrate concentration of 2.95 mg L^{-1} was detected.

Table 1. Mean (±SE) water quality parameters during the experiment

During the experiment, the mean concentration of ammonia varied from 0.03 to 0.09 mg L^{-1} across treatment groups. These concentrations did not present any toxicity risks for the fish or the mussels. The lowest concentration of ammonia was recorded in the 8M group, whereas the highest concentration was recorded in the control (0M) group; however, no significant differences were observed between the groups ($P>0.05$) (Table 1).

Nitrite concentrations remained between 0.10 and 0.63 mg L^{-1} throughout the study. However, it was found that nitrite values were significantly higher in the control groups (0.63 mg L^{-1}) than in the treatment groups containing mussels ($P<0.05$) (Table 1).

The concentration of nitrate remained at 5 mg L^{-1} throughout the experiment for all treatment groups. There was also no significant difference in phosphate concentrations (0.62–0.79 mg L^{-1}) between treatment groups ($P>0.05$) (Table 1).

No TSS was detected at the start of the experiment. However, the control tanks showed a mean concentration of 4.73 mg L^{-1}after 15 days, 1.98 mg L^{-1} after 30 days, 2.73 mg L^{-1} after 45 days, 7.30 mg L^{-1} after 60 days, and 9.55 mg L^{-1} after 75 days, whereas the treatment groups with mussels had

Table 1. Water quality parameters of the experiment

Experimental Groups	NH_3	NO_2	NO_3	PO_4	TSS
Control	0.09±0.06	0.63±0.16^a	5.25±0.04	0.62±0.06	6.53±0.95^a
8M	0.03±0.01	0.10±0.03^b	5.23±0.06	0.75±0.08	3.16±0.34^b
16M	0.05±0.01	0.13±0.02^b	5.27±0.04	0.78±0.04	3.23±0.70^b
24M	0.05±0.01	0.12±0.03^b	5.29±0.02	0.79±0.06	1.74±0.36^b
32M	0.06±0.01	0.12±0.02^b	5.20±0.07	0.69±0.12	2.06±0.17^b

Mean (mgL^{-1}) ± SE (The average of measured values during the trial).
Mean values within the same column having the different superscript are significantly different ($P<0.05$).

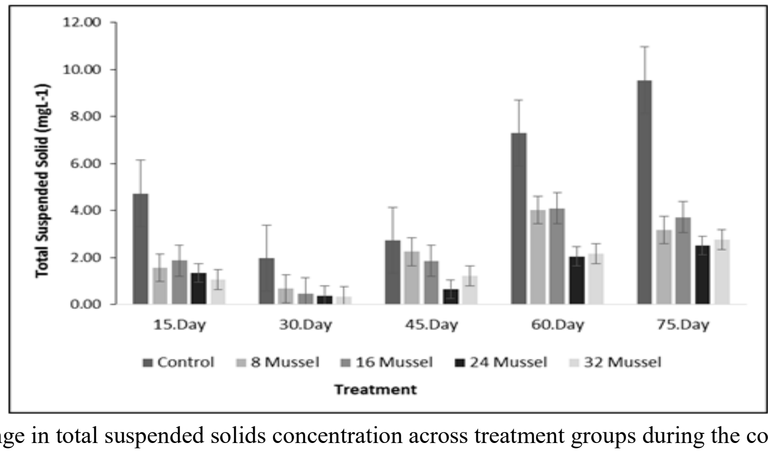

Figure 1. Mean change in total suspended solids concentration across treatment groups during the course of the experiment.

significantly lower levels (Table 1, Figure 1). When the mean concentration of TSS was calculated for the entire experimental period, it was found that the control group had a significantly higher concentration of TSS than the other treatment groups (6.53 vs. 1.74–3.23 mg L^{-1}) (P<0.05). The 24M group had the lowest concentration of TSS (1.74 mg L^{-1}), but there was no significant difference in the concentration of TSS between the treatment groups containing mussels (P>0.05) (Table 1, Figure 1).

Figure 1 shows mean change in the concentration of total suspended solids across treatment groups during the course of the experiment

Thus, we estimated a maximum reduction of 73.35% TSS and 80.95% nitrite between the control and treatment groups (Table 1).

The highest growth of mussels was detected in the 8M group (0.56 mm) (length × width), whereas the lowest growth was observed in the 24M group (0.31 mm). In contrast, WG was the highest in the 24M group (0.29 g) and the lowest in the 16M group (0.17 g). There were no significant differences between treatment groups in the size or WG of the mussels (P>0.05) (Table 2). Mussel SR was 100% in the 8M and 24M groups, 95.67% in the 16M group, and 99% in the 32M group. These differences were also not significant (P>0.05).

Table 2 shows average mussel growth (mm), (g) and survivorship over the course of the experiment.

At the end of the experiment, goldfish in the 32M group were found to have the highest growth rate (Table 3). WG, WGP, and SGR were similar across all groups containing mussels but were significantly lower in the control group (P<0.05).

The best FCR (2.15) was observed in the 32M group, whereas the other treatment groups containing mussels had slightly lower but similar values. However, the control group had a significantly lower performance than the other treatment groups (2.40) (P<0.05). Fish SR was 100% in all treatment groups.

Table 3 shows growth performance and feed conversion ratio of juvenile goldfish (*C. auratus*).

Discussion

During the experiment, the dissolved oxygen level ranged from 6.14 to 7.18 mg/L across the treatment groups, demonstrating that sufficient oxygen was available for the mussels and fish. Neither the water temperature (23±1°C) nor the pH (8.5) had a negative effect on the physiological activities of the mussels. Similar results were obtained for the Pacific oyster *C. gigas* (Miranda *et al*., 2010) and the freshwater mussel *E. complanata* (Mueller *et al*., 2004; McKenzie and Özbay, 2010), demonstrating that the water quality parameters are not affected by the taxon used for filtration (Mueller *et al*., 2004).

Although ammonia levels occasionally increased significantly in the aquariums during the study, these levels remained below the critical sublimit for freshwater ornamental fish (0.2–0.5 mg L^{-1}; Wildgoose, 2001). The ammonia level was higher in the control group than in the treatment groups containing mussels, but this difference was not significant (Table 1). Similar results were obtained in previous studies where lower concentrations of ammonia were recorded in ponds containing the mussel *E. complanata* (Mueller and *et al*., 2004) and the oyster *C. gigas* (Miranda *et al*., 2010), but no significant differences were observed between the treatment and control groups. McKenzie and Özbay (2010) also obtained results similar to ours but reported that ammonia levels occasionally increased significantly in the ponds containing mussels.

The concentration of nitrite was higher in the control group than in the other treatment groups. This indicates that the ammonia generated by the fish was converted into nitrite but that mussels removed this by filtering the particulate matter in the environment. Similarly, previous studies have found lower nitrite levels in tanks containing the mussel *E. complanata* (Mueller *et al*., 2004) and the oyster *C. gigas* (Miranda *et al*., 2010), although these concentrations were not significantly different from the control group. In contrast, McKenzie and Özbay (2010) reported higher nitrite levels in the treatment groups containing mussels, although these were also not significantly different from the control group.

Concentrations of nitrate and phosphate remained well below toxic limits throughout the study in all treatment groups with no significant differences between the groups. This supports the previous findings of Mueller *et al*., (2004) and Miranda *et al*., (2010). In contrast, McKenzie and Özbay (2010) recorded much higher concentrations of both nitrate and phosphate in the groups containing mussels than in the control group, although these differences were

Table 2. Average mussel growth (mm), (g) and survivorship over the course of the experiment

Treatment	Lenght x Width Growth (mm)±SE	Weight Gain (g.)±SE	Survival Rate (%)±SE
8M	0.56±0.44	0.25±0.05	100±0.00
16M	0.46±0.21	0.17±0.04	95.67±4.33
24M	0.31±0.20	0.29±0.05	100±0.00
32M	0.37±0.05	0.25±0.02	99±1.00

Average mussel growth (mm) = Final lenght x width - Initial lenght x width
Average mussel growth (g) = Final wet weight - Initial wet weight

Table 3. Growth performance and feed conversion ratio of juvenil gold fish (*C. auratus*)

	Control	8M	16M	24M	32M
IBW(g)	1.98±0.01	1.98±0.00	1.98±0.01	1.98±0.00	1.98±0.01
FBW (g)	6.53±0.05^{b}	6.99±0.06^{a}	6.83±0.19^{ab}	6.74±0.17^{ab}	7.09±0.12^{a}
WG (g)	4.55±0.05^{b}	5.01±0.06^{a}	4.85±0.19^{ab}	4.76±0.17^{ab}	5.11±0.11^{a}
WGP (%)	227.46±3.78^{b}	254.25±5.53^{a}	245.03±7.88^{ab}	238.01±6.70^{ab}	257.06±6.22^{a}
SGR (%d^{-1})	1.42±0.01^{b}	1.50±0.01^{a}	1.47±0.03^{ab}	1.46±0.03^{ab}	1.52±0.01^{a}
FCR	2.40±0.03^{b}	2.17±0.02^{a}	2.25±0.09^{ab}	2.30±0.08^{ab}	2.15±0.05^{a}
SR (%)	100	100	100	100	100

Mean values within the same column having the different superscript are significantly different (P<0.05)
IBW (g): Initial body weight
FBW (g): Final body weight
WG: Weight gain (g/fish) = (mean individual final body weight – mean individual initial body weight).
WGP: Weight Gain Percentage (%) = Final body weight - Initial body weight / Initial body weight) x 100
SGR: Specific growth rate (%day^{-1}) = [(ln final body weight - ln initial body weight)/days] × 100
FCR: Feed conversion ratio = dry feed fed / wet weight gain.
SR (%): Survival rate

also not significant. These authors suggested that these differences were due to the variation in environmental conditions, particularly temperature, experienced in outdoor ponds. However, Mueller *et al*., (2004), who also conducted their study in outdoor ponds, did not mention any negative effects of environmental conditions. Because the present study was conducted indoors, factors such as water inlet and outlet flow and temperature could be kept constant, allowing the effects of mussels on water quality parameters to be evaluated.

The concentration of TSS in the water was significantly higher in the control group than in the treatment groups containing mussels throughout the study period, but there were no significant differences between the groups containing mussels. This showed that the mussels filtered solid matter from the water and removed it, reducing the concentration of TSS. Miranda *et al*. (2010) similarly reported that the Pacific oyster (*C. gigas)* was effective in filtration but that the number of oysters did not have a direct effect on filtration. Mueller *et al*. (2004) compared the filtration capacity of various fish species and the freshwater mussel *E. complanata* and found that better results were obtained with the mussels, and in comparison with the performance of different freshwater mussels, Musig *et al*. (2012) found that the best filter feeders were *C. boudani* and *C. moreletiana*, but when these species were compared with Asian clams (*C. flumenia*), the latter yielded the best result.

The removal rate of TSS varied from 50.54% to 73.35% across the treatment groups containing mussels. These are similar to the rates reported by Miranda *et al*. (2010), who recorded a maximum TSS removal rate of 73.50%, whereas Jones and Preston (1999) recorded a rate of 38%. Thus, Asian clams efficiently removed the particulate matter generated in the aquariums.

In contrast to our findings, McKenzie and Özbay (2010) reported a much lower concentration of TSS in the control group than in the treatment groups containing mussels. However, this difference may be because the mussels in their study reproduced, which may have expended more energy. In contrast, in our aquariums the mussels were unable to reproduce because of the water temperatures being above the temperature for reproduction of this species.

At the end of the experiment, the fish in the aquariums containing mussels had a significantly better performance in terms of SGR and FCR than those in the control group. Furthermore, the number of mussels in the aquariums did not affect the growth rate of the fish, which supports the previous findings of McKenzie and Özbay (2010).

The highest level of mussel growth at the end of the experiment was observed in the treatment group with the lowest number of mussels, although none of the differences between treatment groups were significant. Similarly, McKenzie and Özbay (2010) found that the growth rate of mussels was higher at a lower stocking density but that there were no significant differences between treatment groups. As the number of mussels increased, the level of environmental stress might have increased and the amount of feed available might have decreased, which may have caused the observed decline in the growth rate of mussels.

The main aim of our study was to investigate whether Asian clams could filter the water, decrease the concentration of TSS, maintain water clarity, and improve the water quality in the aquariums. Our findings demonstrated that the 24M group was the most successful in performing these functions but that all other treatment containing mussels groups were also useful. The second aim of the study was to assess the growth rate of the fish because it is important that they reach market size as soon as possible to maximize profitability. The highest growth rate and best FCR were observed in the 32M group, followed by the 8M, 16M, and 24M groups, respectively, although none of these differences were significant.

Although the SR of goldfish was 100% across all treatment groups, the SR of mussels ranged from 95.67% to 100%; however, no significant differences were observed between the treatment groups. These results support the previous findings of McKenzie and Özbay (2010) but are a little below those of Miranda *et al*. (2010), Jacob *et al*. (1993), and Martinez-Cordova and Martinez-Porchas (2006), who reported a 100% SR for oysters.

Conclusion

In this study, we tested the usefulness of the Asian clam as a biomechanical filter in goldfish aquariums. The optimal density of mussels was also assessed by examining the effect of different stocking densities of mussels on water quality improvement, TSS removal from the water, and fish growth performance.

The polyculture of Asian clams with goldfish did not have any negative effects on water quality or fish health. Furthermore, aquariums containing mussels had improved water quality parameters, decreased concentrations of TSS, and enhanced fish growth rates.

Nitrate, ammonia, and phosphate levels were similar in all treatment groups. However, the 24M group provided the highest removal rate of TSS from the water. All treatment groups containing mussels exhibited better performance with regard to the growth of fish and FCR than the control group, with the 32M group yielding the highest levels.

Because Asian clams are small, they take up little space in an aquarium. Furthermore, because they do not move around much, they do not disturb the esthetic appearance of an aquarium for aquariculture. Therefore, it is concluded that the addition of mussels to ornamental fish aquariums could improve the water quality and contribute to the growth performance of the fish.

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