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STUDIES ON SMALL AQUACULTURE RECYCLING SYSTEMS WITH REFERENCE TO FEED AND FEEDING PRACTICES

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ABSTRACT : **The Performance of three biofilter types (rotating, trickling and submerged) were evaluated in recycled aquacultural systems stocked with Nile tilapia (*Oreochromis niloticus*). The systems consisted of square fiber-glass tanks, each was provided with a simple mechanical filter and one type of the tested biological filters. Three treatments (each with 3 replicates) were stocked with tilapia fingerlings in addition to a control treatment with no biofilter system. Daily weight gain, feed conversion ratio (FCR), ammonia, nitrite and nitrate concentrations were determined over 28 days period. Fish were fed on formulated feed containing 25% crude protein at a rate of 2.5% of their biomass two times a day. Differences in daily weight gains, FCR and concentrations of ammonia nitrite and nitrate among the experimental treatments were statistically evaluated. Best results were achieved with rotating biofilters ($P<0.05$) followed by the trickling and the submersible type.**

INTRODUCTION

Small-scale aquaculture recycling units could represent food fish production system that provide a family with few kilograms of fish per week (Provenzana *et al.*, 1987). Many attempts have been made to utilize recycling water systems to produce tilapia in urban as well as in other environments however, total ammonia level can be a limiting factor for the reuse of water for growing fish (Brunty *et al.*, 1997). Biological filters designed to remove toxic ammonia are generally used to control such a level and usually considered as an integral part of any recycling aquaculture system. They could convert the harmful ammonia forms to less dangerous forms such as nitrate. The purpose of this experiment is to evaluate the performance of three different biofilters in small recirculating systems that may be used in urban areas where a consumer could produce his own food fish.

MATERIALS AND METHODS

This experiment was performed in Aquaculture project, Faculty of Agriculture, Ain shams university, Cairo, Egypt. Experimental fish was Nile tilapia (*oreochromis niloticus*).

Rearing units

The rearing units employed in this study were rounded square (125 x 125 x 55 cm) fiber-glass tanks. These rearing units hold approximately 400 l of water when filled to an operating depth of 30 cm. These tanks were provided with a continuous aeration through a number of air-stones connected to a centeral air-blowers system.

Each rearing tank was provided with waste water treating filtration facilities, that include a simple mechanical filter and one type of the tested biological filters. Mechanical filteration was made by pumping water on a nylon mesh (30 cm diameter 0.1 mm mesh) that holds a layer (10 cm) of cotton wool.

Biological filters

Three different types of biofilters were designed and evaluated in the present study : Rotating (RBF), Trickling (TBF), and submerged (SBF) biological filters.

Rotating biological filter:

The filter material consisted of 50 rigged polyethylene net disks, 32 cm in diameter. The disks were fixed together with a nylon thread to form a drum shaped wheel. This arrangement provided a total surface area of 80000 Cm^2 for biological filtration process, and 0was the basic design for the biological filtration media utilized in all the experimental biological filters employed in the present study.

A stainless steel shaft was fixed in the drum center allowing an easy balanced rotation. The drum wheel mounted on a floating plastic squared ring (30 x 50 cm) so that approximately 45% of the drum was submerged in the water (Fig. 1). A couple of air-stones were placed beneath the biological drum and the air flow was adjusted so that the filter media was revolving regularly at approximately 7-8 rpm.

Trickling biological filter

The trickling filters media was basically similar to that of the rotating filters. It consisted of 50 polyethylene net disks fixed together to form a drum (32 cm in diameter). The drum was placed horizontally in a plastic basket (40 cm in diameter, 25 cm in depth) to operate as a trickling filter. The filter was directly placed in one of the rearing unit corners in such a way that the filter media was exposed to the air. A special water inlet ring was designed and placed on the top of the basket, from which water was continuously sprinkled. The water inlet was joined to a small air-lift pump operating inside rearing unit, delivering approximately 3000 cm^2 of water per minute. This amount was sufficient to keep moisting all the filter media. Special care was taken to ensure that the media was receiving balanced water drops leaving no dry areas on the drum surfaces.

Submerged biological filter

A similar in design drum media filter to that used in the former two filters was to operate as a submersed biological filter. Therefore the drum-like media was placed in a plastic rounded basin 40 cm in diameter. The filter media was completely submersed in water, and water circulation was operated through it by aid of a small air-lift pump operating inside the rearing unit. Water was sprinkled over the basin through a network of plastic pips, whilst water out let was achieved through small holes (1.8 mm^2) on the basin bottom. The number of the holes provided (6.25 cm^2) which allows a water flow rate similar to that of the above type. Strong aeration was provided beneath the biological filter materials through a number of air-stones.

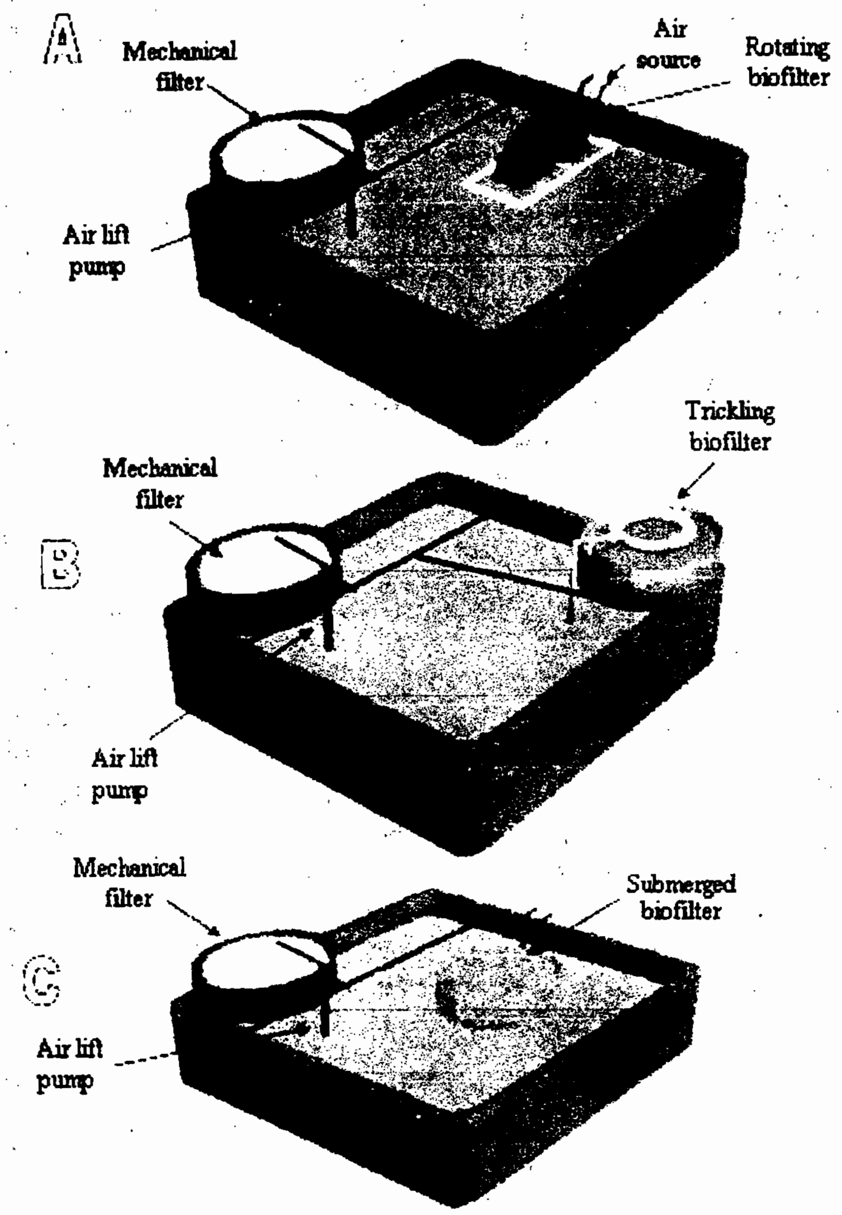

Fig (1).Diagram of rearing unit with : A: Rotating biofilter
B: Trickling biofilter
C: Submerged biofilter

Conditioning of biological filters

Conditioning of the biological filters were accomplished through a period of six weeks normal operation. During which time a group of fish weighing were stocked in the rearing units and were fed twice daily at 2.5% feeding rate of there total biomass. Daily water samples were taken and were analyzed for total ammonia, nitrite, nitrate, pH, total alkalinity, water hardness and temperature.

Experimental procedure

One hundred and eighty fish Nile tilapia (*Oreochromis niloticus*) were randomly divided into 4 treatments differing in their biological filters design with 3 replicates. Each replicate consisted of 15 fish stocked in one of the rearing units. The present treatments included a rotating, trickling, submerged filters, and without biological filters (control treatment).

An acclimating period of two weeks was allowed before the commence of the experiment. Experimental fish were grown in the above rearing units for 4 weeks. They were fed 2 times a day (900 and 1600 h) on a formulated diet containing 25% crude protein at a rate of 2.5% of the total biomass. Water temperature was maintained at 28°C by a thermostatically controlled glass heater. One quarter of the water in the experimental rearing units was exchanged by an equivalent volume of fresh water aerated and kept at the same temperature.

Water parameters were daily measured 3 times a day at (900, 1300 and 2000 h). These included temperature, pH and Oxygen. Samples of water were taken at 0, 2, 4, 6 and 8 hours after offering the diets to fish, these samples were analysed for total ammonia, nitrite and nitrate.

Statistical analysis

All data were analyzed using one-way analysis of variance (SAS/PC statistical software, SAS institute Inc., Cary, NC). Multiple comparisons among means were made with the Duncan,s Multiple Range Test (Duncan , 1955).

RESULTS AND DISCUSSION

Growth performances

Final body weights of fish were significantly ($P<0.05$) affected with the type of the biological filter. Final live body weight of fish incrased by 7.87, 7.57 and 3.94%, respectively on fish groups reaned in TBF, RBF, a[nd SBF when compared with the control group (Table 1).

Table 1. Live body weight of tilapia grown in systems with different biological filter types.

Biofiter type / Week	RBF	SBF	TBF	Control (without biofilter)	Significance
0	77.97 ± 1.52^{a}	78.40 ± 1.31^{a}	79.74 ± 1.01^{a}	78.30 ± 1.93^{a}	ns
2	91.93 ± 1.28^{a}	89.90 ± 1.57^{a}	93.36 ± 0.58^{a}	89.30 ± 1.67^{a}	ns
4	107.60 ± 1.17^{a}	103.97 ± 1.94^{ab}	1.790 ± 1.06^{a}	100.03 ± 1.57^{b}	*

Values in the some raw with different superscripts are significantly different (P<0.05).
n.s: not singificant *: (P<0.05)

The average daily weight gains of fish groups reared in systems varying in their biofilters are presented in Table 2. Analysis of variance showed a significant differences (P<0.01) in daily weight gains of fish among the different treatments.

Table 2 : *Daily gain (g) of tilapia reared in recycling systems with different* types of biological filtration.

Biofilter type / Week	RBF	SBF	TBF	Control	Significance
0-2	1.00 ± 0.03^{a}	0.82 ± 0.02^{b}	1.01 ± 0.03^{a}	0.79 ± 0.04^{b}	**
2-4	1.12 ± 0.04^{a}	1.01 ± 0.04^{a}	1.02 ± 0.04^{a}	0.77 ± 0.01^{b}	**
0-4	1.06 ± 0.04^{a}	0.91 ± 0.03^{b}	1.02 ± 0.03^{a}	0.78 ± 0.02^{c}	**

Values in the same raw with different superscripts are significantly different (P<0.05). **: (P<0.01)

The average daily weight gain of fish reared in trickling and rotating biofilters were higher than that reared in a system with a submerged biofilter. Furthermore, fish reared in systems equipped with biofilters grow faster than those reared in system with no biofiltration (control treatment).

The average daily gain for RBF, TBF, SBF, percentages were 135-90%, 130.77%, 116.67% when compared with that of control reatment as 100%.

Relative growth (daily body gain (g) /100g body weight) of fish was signficantly affected with the type of the biological filters. Relative growth of tilapia increased by 31% , 24% and 15% , respectively , on fish groups reared in RBF , TBF and SBF when compared with the control group (Table 3).

Table 3: Relative growth,*of tilapia reared in recycling systems with different types of biological filtration.

Week \ Biofilter type	RBF	SBF	TBF	Control	Significance
0-2	1.18± 0.05^{a}	0.98± 0.01^{b}	1.17±0.05^{a}	0.94±0.04^{b}	**
2-4	1.12± 0.05^{a}	1.04± 0.03^{a}	1.01± 0.04^{a}	0.81± 0.01^{b}	**
0-4	1.14± 0.05^{a}	1.00± 0.02^{b}	1.08± 0.04^{a}	0.87± 0.2^{c}	*

* Relative growth = daily body gain (g) /100g body weight
Values in the same raw with different superscripts are significantly different (P<0.05).
*: (P<0.05) **: (P<0.01)

The results of daily weight gain are in agreement with that reported by Twaraska *et al.* (1997). These authors used a trickling filter with an intensive recirculating fish production system to grow approximately 2170 tilapia fingerlings from 3.6 to 507 g in 177 days (daily gain 2.84 g).

Provenzano and Winfield (1987), reared 424 tilapia hybrid fry weighing a total of 177 g for 146 days in rearing units equipped with a rotating biological contactor. They were able to harvest 48.6 kg of fish (average daily gain 0.75g). Similarly, Papoutsaglou and Tziha (1996) reported a growth rate in the range of 0.49-1.43 g/ day for blue tilapia when reared for 200 days under recalculated water conditions.

Food conversion ratio

Values of feed concersion ratio of tilapia reared in the tested systems with different biofilter types are presented in Table (4) and analysis of variance showed that thre were a significant (P<0.01) differences in FCR during the experimental periods (0-2,2-4 and 0-4 weeks)

Table 4: Food conversion ratio (FCR) of tilapia fingerlings reared in recycling systems differing in their biological filter types.

Week \ Biofilter type	RBF	SBF	TBF	Control	Significance
0-2	1.96± 0.09^{a}	2.39± 0.03^{b}	1.97±0.09^{a}	2.51±0.12^{b}	**
2-4	2.06± 0.10^{a}	2.24± 0.06^{a}	2.31± 0.11^{a}	2.91± 0.08^{b}	**
0-4	2.02± 0.09^{a}	2.31± 0.05^{b}	2.14± 0.09^{a}	2.71± 0.07^{c}	**

Values in the same raw with different superscripts are significantly different (P<0.05).
**: (P<0.01)

The smallest values (best) of FCR were abtained with RBF followed by TBF, SBF, and the control group When the values index with the value of control as 100% , it seems that the fish reared in RBF showed the best percentage for FCR (75.54%), wherase fish reared in the TBF and SBF systems showed values of 78.97 % and 85.24 % , respectively .

Provenzano and Winfield (1987), reported an overall feed conversion ratio in the range of 1.25 for tilapia hybrid reared in recirculating system equipped with a ratating biological contractor

Ammonia, nitrite and nitrate concentration

The effects of biological filter type on the concentration of ammonia, nitrite and nitrate (mg/l) in the rcycling water systems are presented in (Tables 5, 6 and 7). Analysis of variance showed that there were significant differences (P<0.01) among different types of biofilter on the concentration (mg / l) of ammonia, nitrite and nitrate RBF system showed the lowest ammonia conc. values followed by that of the SBF then that of TBF however highest values were recorded in the control group (0.71 to 2.22 mg/l).

On the other hand, the highest values of ammonia concentration. were observed 4 hours after feeding in all experimental groups. Ammonia concentration. increased gradually after feeding to reach a peak 4 hours after feeding (Fig. 2). TBF and RBF systems showed the lowest nitrite concentration at all times after feeding from 0-8 hours (Fig. 3). These values ranged from 0.46 to 0.83 mg/l and (0.48 to 0-91mg/l) followed by the SBF group (0.53-0.86 mg/l) then the control group (0.77 to 1.43 mg/l).

Patterns of nitrite conc. in the water after feeding followed the same trend of ammonia. Nitrate in the control group showed the highest levels at all times after feeding. Nitrate concentration. in the different experimental systems increased gradually after feeding, reaching a peak after feeding ,4 hours , however it was almost constant in control group(Fig.4).

Table 5: Ammonia concentration (mg/l) in recycling water systems differing in their biological filter type, and post feeding times.

Biofilter type / Time (h) After feeding	RBF	SBF	TBF	Control	Significance
0	0.24 ± 0.01^{c}	0.31 ± 0.01^{b}	0.32 ± 0.01^{b}	0.71 ± 0.02^{a}	**
2	0.37 ± 0.03^{c}	0.49 ± 0.01^{bc}	0.54 ± 0.04^{b}	1.05 ± 0.05^{a}	**
4	1.26± 0.10d	1.67± 0.03c	1.86 ± 0.04^{b}	2.22 ± 0.03^{a}	**
6	0.95± 0.06b	1.15 ± 0.10^{b}	1.03± 0.03	2.10 ± 0.03^{a}	**
8	0.28± 0.12c	0.36 ± 0.01^{b}	0.40 ± 0.02^{b}	2.09 ± 0.01^{a}	**

Values in the same raw with different superscripts are significantly different (P<0.05).
**: (P<0.01)

Table 6: Nitrite concentration (mg/l) in recycling water systems with different biological filter types, and post feeding times.

Biofilter type / Time (h) after feeding	RBF	SBF	TBF	Control	Significance
0	0.48± 0.03[b]	0.53± 0.03[b]	0.46±0.01[b]	0.77±0.04[a]	*
2	0.69±0.01[bc]	0.73±0.01[b]	0.67±0.01[c]	1.07±0.02[a]	**
4	0.91±0.01[b]	0.86±0.02[bc]	0.83±0.03[c]	1.43±0.02[a]	**
6	0.69±0.03[b]	0.68±0.01[b]	0.70±0.02[b]	1.33±0.02[a]	**
8	0.55±0.02[b]	0.53±0.01[b]	0.58±0.01[b]	1.21±0.01[a]	**

Values in the same raw with different superscripts are significantly different ($P<0.05$).
*: ($P<0.05$) **: ($P<0.01$)

Table 7: Nitrate concentration (mg/l) in recycling water systems differing in their biological filter type, and post feeding times.

Biofilter type / Time (h) after feeding	RBF	SBF	TBF	Control	Significance
0	0.89± 0.08[b]	1.07± 0.02[a]	0.91±0.05[a]	0.13±0.02[c]	**
2	1.76±0.04[a]	1.84±0.05[a]	0.537±0.03[b]	1.11±0.00[c]	**
4	2.02±0.03[a]	2.07±0.06[a]	2.05±0.07[a]	0.13±0.02[b]	**
6	1.14±0.03[b]	1.83±0.08[a]	1.79±0.08[a]	0.12±0.00[C]	**
8	0.91±0.03[b]	1.32±0.07[a]	0.99±0.03[b]	0.09±0.01[C]	**

Values in the same raw with different superscripts are significantly different ($P<0.05$).
**: ($P<0.01$)

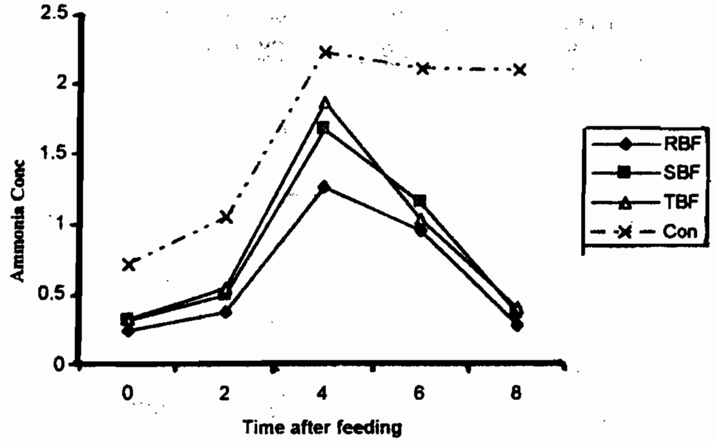

Fig. (2): Ammonia concentration in recycling water systems differing in their biological filter type.

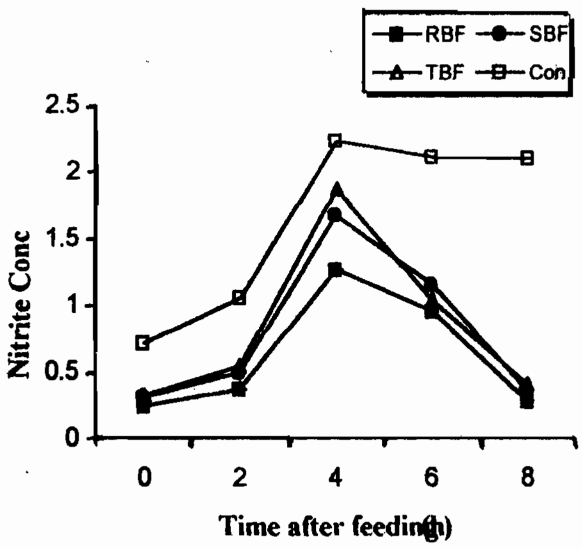

Fig. (3): Nitrite concentration in recycling water systems differing in their biological filter type

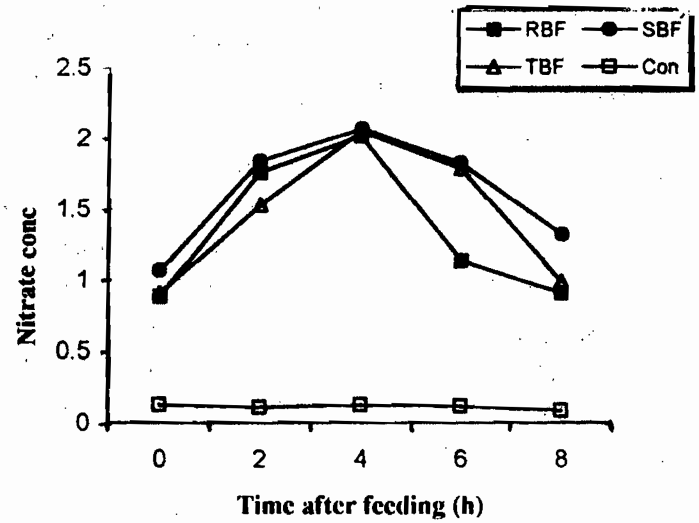

Fig. (4): Natrite concentration in recycling water systems differing in their biological filter type.

The present results of this experiment are in agreement with that of Twaroska *et al.* (1997). They reported a similar total ammonia nitrogen (TAN) value of 0.62 ± 0.37 mg/l, when using trickling biofilter in recalculating system for tilapia. Similarly, Provenzano and Winfield (1987), found that TAN concentration. was in the range 1-2 mg/l in a recirculating system equipped with rotating biofilter, when used for growing tilapia hybrids. Reyes Delos and Lawson (1996), reported a linear increase in TAN concentration. in a recirculating system from 0.45 to 0.89 mg/l as feeding rate increased (feeding rate was nearly 2% of body weight) from 1.4 to 2.0 kg / day, this is equivalent to a 0.73 mg TAN/l increase per kg of feed.

Trickling filters are commonly used for nitification in fish farms (Kamstra et-al. 1998). There filters are relatively easy to build and operate and have an important additional function in degassing and re-oxygenating the water. Twaroska *et al.* (1997), performed a study on intensive recirculating fish production system. A total of 2170 fingerling tilapia were gown from 3.6 to 507 g in 177 days in a 20-m^3 four –zone, tank. The system involved a high- rate lincar –path trickling biological filter for nitrification. Bases on six efficiency tests with a mean

(TAN) concentration in the culture tank of 0.62 mg/l, the biofilter removed approximately 65% on a single pass through the filter with an average removal rate per unit of filter surface area of 0.33 g TAN/m^2/day. The biofilter media consisted of 235 pieces (10.6x 10.6 x76cm) placed in two layers for a total volume of 2.0 m^3 and was contained in a 3.66-m long corrugated metal pipe, 1.37-m in diameter, with 3- m of the pipe below ground surface level. The specific area of the media was 416m^2/m^3.

The supply of dissolved oxygen for the bacteria has been observed to be the principal factor limiting the carrying capacity of submerged filters used in high density recirculating systems. Manthe et al (1988), reported that 1m^3 of 2-cm limestone (submerged rock filter) could support bacterial consumption of 1.2 kg O_2 /day without limitations that lead to filter failure by physical clogging or pH decline. Therefore, oxygen concentrations in a submerged rock filter must not fall below 2 mg/ liter if complete nitrification is to be assured. Baseline water quality conditions varied according to the extent of fish loading in the systems, but remained less than 0.5-mg- N/ liter for both ammonia and nitrite. Twaroska *et al* (1997), were able to grow over one metric ton of tilapia in a 20-m ^{3} recycling system, with mean TAN concentration of 0.62 ± 0.37 mg /l and NO_2-N concentration of 1.62 mg /l, using a high- rate linear–path trickling bioflter.

Studies on biofilters in fish production systems have reported some comparisons between various filter types. In one study of TAN removal efficiency, a rotating biological contractor (RBC) was found to provide the best removal efficiencies: 14-82% compared with a trickling filter (23-52%) and a fluidized sand bed filter (8-32%) Miller and Libey, 1985). Rogers and Klemetson (1985) tested a RBC, biodrum and trickling filter. The RBC removed ever 90% of TAN and the other two filters, even though they had a greater sur face area, removed 80 and 50% of TAN, respectively.

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دراسات عن النظم المغلقة الصغيرة لزراعة الأسماك وأهمية نوع الغذاء وأساليب التغذية

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أجريت هذه الدراسة فى مزرعة الاسماك بكلية الزراعة بجامعة عين شمس لتقييم أداء ثلاثة أنواع من المرشحات البيولوجية (المرشح البيولوجى الدوار rotating biofilter والمرشح البيولوجى بالرش trickling biofilter لمرشح البيولوجى المغمور (submerged biofilters)عند إستخدامها فى نظم مغلقة صغيرة لزراعة الاسماك aquacultural recycled systems تربى فيها اسماك البلطى النيلى. والوحدة التى يتم إستخدامها عبارة عن حوض من الفيبر جلاس مربع دائرى الجوانب مزود بمرشح ميكانيكى بسيط وأحد المرشحات البيولوجية التى يتم أختبارها. تم عمل ثلاثة معاملات كل معاملة تمثل نوع من الثلاثة مرشحات البيولوجية بالإضافة الى معاملة رابعة لا تحتوى على مرشح بيولوجى لإستخدامها كمعاملة مقارنة بكل معاملة ثلاثة مكررات غذيت الاسماك على عليقة تحتوى على ٢٥% بروتين خام بمعدل ٢,٥% من الوزن الحى للأسماك كل يوم مرتين يومياً.

تم حساب كل من معدل النمو اليومى ونسبة تحويل الغذاء كما تم تقدير تركيز الامونيا والنيتريت والنترات (ملجم / لتر) فى الماء لمدة أربعة اسابيع. تم اختبار معنويات الفروق (عند احتمال اقل من ٠.٠٥) بين المعاملات المختلفة بالنسبة لكل من معدل النمو اليومى ونسبة تحويل الغذاء وتركيز الامونيا والنيتريت والنترات.

أظهرت النتائج أن المرشح البيولوجى الدوار هو الاحسن أداء يليه المرشح البيولوجى بالرش ثم المرشح البيولوجى المغمور.