Acta Agraria Kaposváriensis (2002) Vol 6 No 2, 277-283
Kaposvári Egyetem, Állattudományi Kar, Kaposvár
University of Kaposvár, Faculty of Animal Science, Kaposvár

Studies on the effect of nitrate selective resin on the water quality and growth rate of common carp (*Cyprinus carpio* L.) reared in recirculating system

T. Koltai, Cs. Hancz, I. Magyary, P. Horn
University of Kaposvár, Faculty of Animal Science, Kaposvár, H-7400 Guba Sándor u. 40., Hungary

ABSTRACT

Intensive rearing of cultured fish species in recirculating systems is growing worldwide due to the limited capacity of outdoor rearing ponds whereas the regulations of environmental protection can be secured. The accumulation of nitrate which is a metabolic product derived from ammonia is one of the most serious problems in closed rearing systems having harmful effects on the growth rate and fecundity of fish. The nitrate level can be decreased traditionally with water exchange or filtering plants. Recently the application of nitrate selective ion exchange resin is spreading as a new technique. The main aim of our experiment was to study the efficiency of this new technique on the growth rate of common carp reared in an experimental recirculating system.
(Keywords: nitrate selective resin, water quality, *Cyprinus carpio*)

INTRODUCTION

Aquaculture is one of the most dynamically growing sectors producing high quality animal protein. While extensive fish-breeding is performed in ponds, the intensive production is done whether in closed recirculating or flow-through systems. In lack of water recirculating systems are becoming more and more widespread as they can be settled anywhere.

Ammonia is one of the most significant metabolic product of fish. It is transformed into nitrite by *Nitrosomonas* bacteria that can be found on the biological filtering surface of recirculating systems, then *Nitrobacters* transform it into nitrate that accumulates in the system because of oxidative conditions (*Van Rijn* and *Rivera*, 1990). As the final product of the oxidisation of ammonia, nitrate can reach outstanding concentrations in nitrifying recirculating systems (*Van Rijn*, 1996). The highest concentrations measured exceeded 400-500 mg/l NO_3-N (*Otte* and *Rosenthal*, 1979; *Honda et al.*, 1993). The measured maximum values vary by system and indicate the necessity of water exchange and denitrifying activity. The process of denitrification is fulfilled by facultative anaerobe bacteria, which in lack of oxygen and in the presence of organic matters, as final electron acceptors, are able to utilise nitrate, nitrite, dinitrogen oxide and nitrogen monoxide and transform them into a final product, N_2 (*Payne*, 1973). Although most recirculating systems are aerobe, these organisms usually develop in the zone of organic sediment. It is the same in the filter of all nitrifying systems (*Dalsgaard* and *Revsbech*, 1992; *Watanabe et al.*, 1992), and also in other aquaculture facilities (*Kawai et al.*, 1964; *Hirayama*, 1974; *Bullock et al.*, 1994).

The undesirable ammonia, nitrite and nitrate, in a small amount are not toxic to aquatic organisms. However their high concentration with low buffer capacity and low pH is toxic in aquatic cultures. For instance, it is dangerous to the respiration of octopuses (*Hirayama*, 1966) and in fresh water to some species of ornamental fish (*Yirshkovich*, 1994 cit. *Van Rijn*, 1996) where it hinders the development of eggs. The nitrate content should always be controlled because of its toxic effect. After getting into the body of fish, nitrate leads to the formation of the so-called "methaemoglobinemia" as a result of the interactions with haemoglobin. This may end in death by suffocation in case of high concentration (*Helder* and *Vries*, 1983; *Alleman*, 1985).

According to our current knowledge, the removal of nitrate from closed fish breeding facilities could be accomplished either by partial water exchange or by plants if not an anaerobe denitrifying unit is installed. The local removal of nitrate would be a great possibility for reducing high nitrate content. In connection with this, the effectiveness of micro-organisms that reduce nitrite and nitrate - including denitrifiers- has been examined recently (*Betlach* and *Tiedje*, 1981; *Wilderer et al.,* 1987). There is a high nitrite content in intensive fish breeding systems because of the low oxygen content of water. As a consequence, nitrification is unfinished, what is more, denitrification and the transformation of organic matters are also hindered (*Van Rijn* and *Rivera*, 1990; *Van Rijn* and *Sich*, 1992).

Due to considerations on environmental and sanitary matters, the ministries of the environment have made strict rules in most countries for the permissible nitrate content of effluent water, which can not be over 11.6 mg/l according to the EU standard. As we are informed nobody has tried to remove nitrate from fish breeding systems by using nitrate selective ion exchange resin until now, however this method could easily become the most profitable and modern one despite the higher initial investment.

The aim of our experiment was to study the efficiency of this new technique on the growth rate of common carp reared in an experimental recirculating system.

MATERIALS AND METHODS

The experiment was carried out in the Fish Laboratory of the Faculty of Animal Science of the Kaposvár University between January 8 and March 19 in 2001. The experimental stock was one-year-old mirror carp. The experiment lasted for 10 weeks preceded by a conditioning period of 11 days. (The conditioning could be so short because the fish were reared in the laboratory from the autumn harvest and were already adapted to the artificial keeping conditions.)

Fish were stocked in four 150 l plastic troughs, 20 individuals in each. Total initial fish biomass/trough varied between 2.26 and 2.42 kg, consequently the stocking density was 15.71±0.44 g/l at the beginning of the experiment. Fish were weighed individually in the beginning and at the end of the experiment. Fish keeping troughs worked in a recirculating system where water was supplied from a tank by gravity and the effluent water of troughs was pumped back to the tank of supply after flowing through biofiltering unit. The total volume of the system was 850 l. The average water flow was measured as 1.5 l/minute that corresponds to a change of 14.4 times/day in the troughs.

In the first 42 days period of the experiment 2 kg nitrate selective resin was placed in the tank of water supply. This type of resin is generally used for nitrate removal from drinking water. The resin was packed in a textile bag that was fixed under the water inlet. At the beginning of the second period, that was considered as control, the resin was removed from the system and the total water volume was changed to tap water. This period lasted only for 14 days and was terminated because of the drastic deterioration of the water quality. (In terms of fish biomass the final weight of the first period is the beginning weight of the second one.)

Main nitrogen forms (ammonium, nitrate and nitrite) were determined by photometer (Viscolor PF-10), pH was measured by HANNA Watercheck and dissolved oxygen by spectrophotometer (HI-93732N) from samples taken weekly from every trough. Water temperature changed between 19.5 and 21.0°C during the experiment.

Fish were fed ad libitum by floating carp feed fabricated by the Feed-Full Co., Hernád, Hungary. Nutrient content of the feed is given in *Table 1.*

Table 1

Chemical composition of the feed used in the experiment (%)

Dry matter	Raw protein	Raw fat	Raw fibre	Raw ash	N-free extract*
86.5	30.1	5.2	1.6	5,6	44.0

**Calculated value*

Statistical data analyses were carried out by SPSS for Windows 7.5 (1996). Means of the nitrate and oxygen level at the 7th and 14th day of resin treated and control period were compared by Student's t-test. The same means within periods were compared by the Student-Newman-Keuls test in one-way ANOVA.

RESULTS AND DISCUSSION

Stocking density has increased from the initial 15.71±0.44 to 20.82±0.93 g/l for the 42nd day of the experiment and this value changed for 21.79±1.13 g/l at the end of the second period. The specific growth rate of fish (S.G.R.) showed an average of 0.67±0.007%/day in the first period when nitrate removal by resin was applied. This value decreased to 0.32±0.263%/day in the final 14 days when the system worked without nitrate removal. The increased standard deviation clearly indicates deteriorating keeping conditions.

Feed conversion showed the excellent 1.32±0.17 value in the first period while this trait could not be evaluated for the second period because of the extremely high values observed in two troughs due to the near zero growth.

Changes in the nitrate level during the first and second period can be followed in *Figure 1* and *2*. There is a significant growth of nitrate in the first three weeks in the resin treatment period but even the highest concentration measured (132.5 mg/l) is much less than values reported by *Otte* and *Rosenthal*, 1979 and *Honda et al.*, 1993 for similar recirculating systems. It is remarkable that nitrate remained in the same range in the second half of the first period while nitrite and ammonium were below the level of measurability. Nitrate concentration has reached to 135 mg/l at the end of the second (control) period while parallel to it nitrite was 0.43 mg/l and ammonia 0.1 mg/l. These metabolite levels proved to be intolerable for common carp causing mortality and therefore the experiment was terminated. Evidently nitrate changing capacity of the resin came to its end for this time at the given proportions (2 kg:850 l:12.5 kg of resin:water:fish biomass).

The first rearing period had to be terminated because of the drastic fall of dissolved oxygen occurring at the end of the period. Oxygen showed quite elevated levels until that time as it can be seen in *Figure 3* and *4.* Dissolved oxygen content dropped to 1.45 mg/l for the end of the second, "without resin" control period that also has contributed to the final deterioration of the rearing conditions.

Figure 1

Change of nitrate concentration during the resin treated period (means with standard deviations)

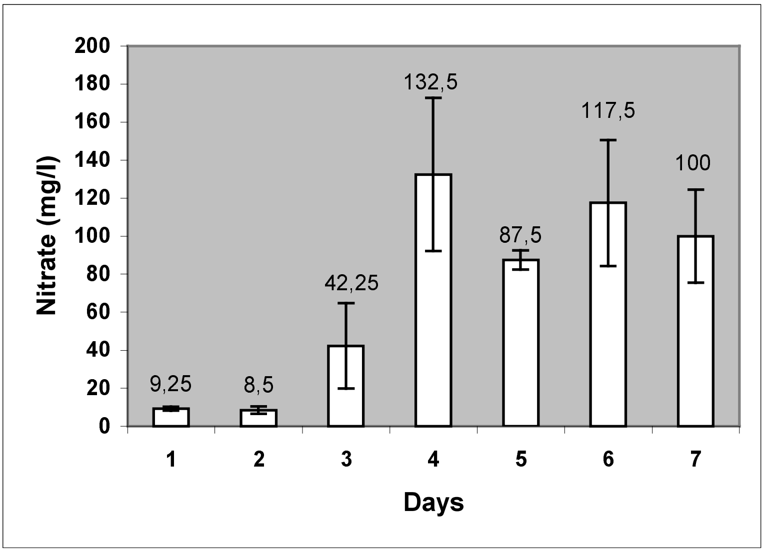


Figure 2

Change of nitrate concentration during the control period (means with standard deviations)

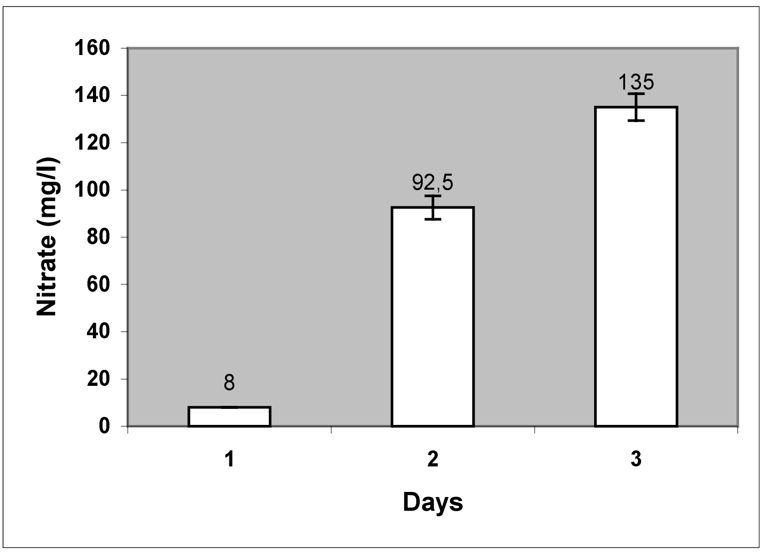


Figure 3

Change of dissolved oxygen during the resin treated period (means with standard deviations)

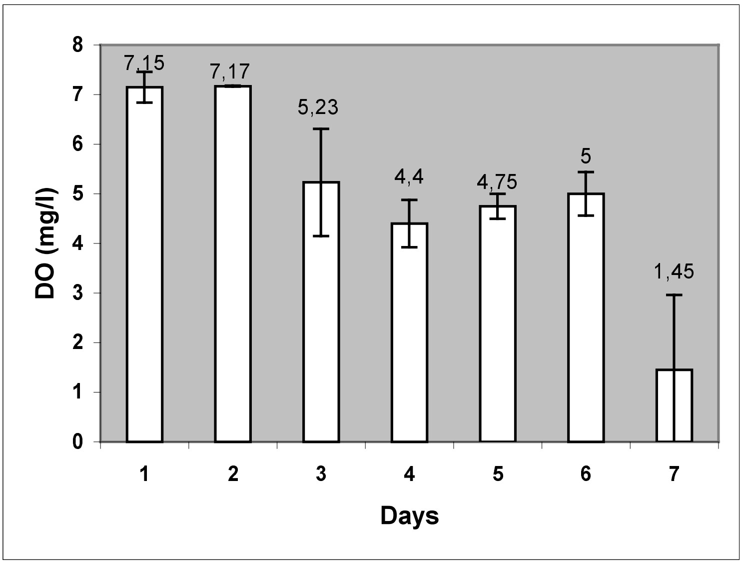
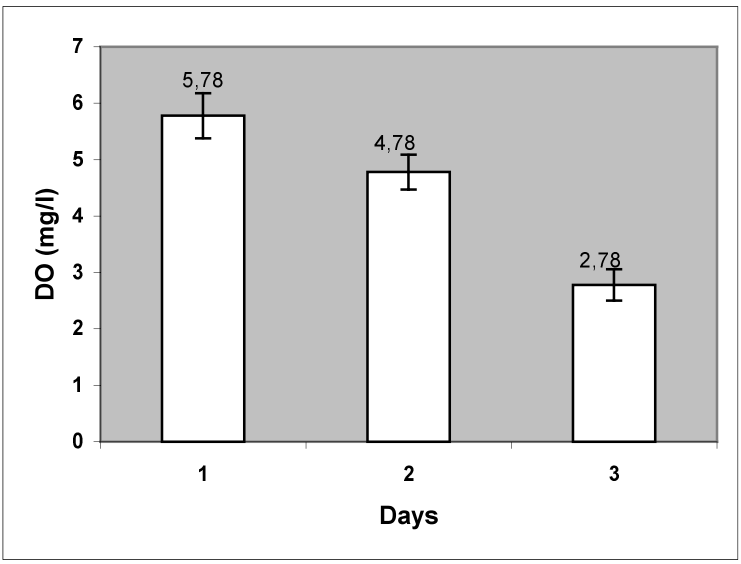


Figure 4

Change of dissolved oxygen during the control period (means with standard deviations)



CONCLUSIONS

It was proved that nitrate changing resin, normally used for drinking water treatment, can be utilised in closed recirculating fish rearing systems. 3.1 kg total gain of common carp was achieved in an 850 l rearing facility with 2 kg of resin applied in 6 weeks of rearing. However the initial investment of this method is relatively high it can be profitable especially considering the fact that this resin is easily renewable with common salt solution and can be used in several successive periods.

Further investigations are needed to determine the necessary rearing parameters for other, more sensitive fish species, but the use of nitrate selective resin seems to be promising especially in experimental recirculation systems for fish rearing, hatcheries or ornamental fish production.

REFERENCES

Alleman, J.E. (1985). Elevated nitrate occurrence in biological wastewater treatment systems. Water Sci. Technol., 17. 409-419.

Betlach, M.R., Tiedje, J.M. (1981). Kinetic explanation for accumulation of nitrite, nitric oxide and nitrous oxide during bacterial denitrification. Appl. Environ. Microbiol., 42. 1074-1084.

Bullock, G., Hankins, J., Heinen, J., Starliper, C., Teska, J. (1994). Qualitative and quantitative bacteriological studies on a fluidized sand biofilter used in a semiclosed trout culture system. Biol. Rep., 17. 1-14.

Dalsgaard, T., Revsbech, N.P. (1992). Regulating factors of denitrification in tricling filter biofilms as measured with the oxygen/nitrous oxide microsensor. FEMS Microbiol. Ecol., 101. 151-164.

Helder, W., de Vries, R.T.P. (1983). Estuarine nitrite maxima and nitrifying bacteria (Ems-Dollard estuary). Neth. J. Sea Res., 17. 1-18.

Hirayama, K. (1966). Influences of nitrate accumulated in culturing water on *Octopus vulgaris*. Bull. Jpn. Soc. Sci. Fish., 32. 105-111.

Hirayama, K. (1974). Water control by filtration in closed culture systems. Aquaculture, 4. 369-385.

Honda, H., Watanaba, Y., Kikuchi, K., Iwata, N., Takeda, S., Uemoto, H., Furata, T., Kiyono, M. (1993). High density rearing of Japanese flounder, *Paralichthys olivaceus,* with a closed seawater recirculation system equipped with a denitrification unit. Suisanzoshoku, 41. 19-26.

Kawai, A., Yoshida, Y., Kimata, M. (1964). Biochemical studies on bacteria in aquarium with circulating system. I. Change of the qualities of breeding water and bacterial population of the aquarium during fish cultivation. Bull. Jpn. Soc. Sci. Fish., 30. 55-62.

Otte, G., Rosenthal, H. (1979). Managment of closed brackish-water system for high density fish culture by biological and chemical water treatment. Aquaculture, 18. 169 - 181.

Payne, W.J. (1973). Reduction of nitrogenous by microorganisms. Bacteriol. Rev., 37. 409-452.

SPSS for Windows (1996). Release 7.5, Copyright SPSS Inc., 1989-96.

Van Rijn, J. (1996). The potential for integrated biological treatment systems in recirculating fish culture. A rewiew. Aquacult. Eng., 139. 181–201.

Van Rijn, J., Rivera, G., (1990). Aerobic and anaerobic biofiltration in an aquaculture unit-Nitrite accumulation as a result of nitrification and denitrification. Aquacult. Eng., 9. 217-234.

Van Rijn, J., Sich, H. (1992). Nitrite accumulation by denitrifying bacteria isolated from fluidized bed reactors operated in an aquaculture unit. In: B. Moav. V. Hilge and H. Rosenthal (Editors), Progress in Aquaculture Research. Spec. Publ. No. 8, European Mariculture Society, Bredene, Belgium. 17-40.

Watanabe, Y., Masuda, S., Ishiguro, M. (1992). Simultaneous nitrification and denitrification in microaerobic biofilms. Water Sci. Technol., 26. 511-522.

Wilderer, P.A., Jones, W.L., Dau, U. (1987). Competition in denitrification systems affecting reduction rate and accumulation of nitrite. Water Res., 21. 239-245.

Corresponding author:

Csaba Hancz
University of Kaposvár, Faculty of Animal Science
H-7401 Kaposvár, P.O.Box 16., Hungary
Tel.: 36 82 314 155, Fax: 36 82 320 175
e-mail: hancz@mail.atk.u-kaposvar.hu