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Enhancement of Foam Floatation Efficiency by Dissolved Air Flotation Reactor

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ABSTRACT

Foam fractionation or foam floatation technology has been introduced to remove fine particles in the Recirculation Aquaculture System (RAS). The main objective of this study was to assess the effect of a dissolved air flotation reactor on foam floatation efficiency in a conventional RAS. In this study, two different types of air bubble producers were tested for 30 days: dissolved air flotation reactor was compared to a commercialized air bubble producer in a skimming column. Nitrogen concentrations and particles removal rates were measured every other day during the study. The results showed that average rates of ammonia and nitrite concentration were lower in the system equipped with air flotation skimmer compared to those in the air bubble system (0.39 and 0.35 versus 3.45 and 0.65 mg L^{-1}, respectively; $P< 0.05$). However, nitrate concentration was not influenced by the foam floatation systems ($P> 0.05$). Nitrogen concentrations were almost similar in the two treatments up to day 15 of the study and then showed higher values for the air bubble system.Total particle collection was significantly higher in the systems containing air flotation skimmer (296.1 versus 276.4; $P< 0.05$), though daily collected particle was almost similar in both systems at the end of the study. In conclusion, dissolved air flotation skimmer was able to remove a larger portion of particles rendering improvement of water quality in RAS.

Keywords: Bio-filter, Nitrogen Concentration, Particles separation, Recirculation aquaculture system, Water quality.

INTRODUCTION

Aquaculture industry has shown a fast growth during past 30 years (FAO, 2012). However, shortage of natural resources such as fresh water and land (Piedrahita, 2003) and also environmental degradation (Amirkolaie, 2011) are challenges facing further development of aquaculture. Recirculation Aquaculture System (RAS) may meet the current restrictions in aquaculture industry due to low usage of land and water (Timmons and Ebeling, 2010). Moreover, RAS also allows fish production throughout the year and production sites can be built closer to market (Timmons and Ebeling, 2010).

Rapid and efficient solid waste removal are key factors to determine successful operation of RAS (Brambilla *et al.,* 2008) and also to reduce the impact of aquaculture wastewater on the environment (Amirkolaie, 2005). The accumulation of solids in RAS increases stress in fish (Klontz *et al.*, 1985; Braaten *et al*., 1986), reduces nitrification rate (Kruner and Rosenthal, 1987) and clogs bio-filters (Timmons and Ebeling, 2010).

A number of solids separation technologies have been introduced in intensive aquaculture treatment systems. Those can be divided into two main groups of mechanical and gravitational methods. Rotating micro-screen, which is often being installed at farms (Cripps and Bergheim,

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2000; Barrut *et al.,* 2013), has been known as a popular method of mechanical particle separation (Brambilla *et al.,* 2008). The treatment efficiency of drum filters varies over a range of 67–97% for suspended solids, 21–86% for total P, and 4–89% for total N mostly in particulate form (Twarowska *et al.,* 1997). However, the conventional technologies for solids separation are not efficient in removing fine solids smaller than 50 µm from wastewater (Brambilla *et al.*, 2008). Solid sedimentation can be used as a simple and high-energy efficient method for particle removal (Rawat *et al.,* 2011), although this technique works only for large-sized and high-density particles (Amaro *et al.,* 2011; Chen *et al.,* 2011).

Foam floatation technology is an alternative to remove fine particles from the wastewater; this technology can be included in water treatment systems to directly remove dissolved and fine suspended solids (Brambilla *et al.,* 2008). Bubbles produced near the bottom of chamber gradually go up continuously through the surface of the column. Surface-active particles become attached to these bubbles when bubbles are rising to the surface so that the fine particles discharged from the wastewater are collected. In addition, foam floatation efficiency in fine solid removal depends on bubble size, concentration of the solids, air-to-water ratio, surface chemistry of the solids, and the surfactant concentration in the water (Huguenin and Colt, 1989; Summerfelt, 1999). Being cost-effective and easy to use, foam floatation foam fractionation technology is generally preferred over other solid removal systems (Suzuki *et al.,* 2008; Brambilla *et al.,* 2008; Park *et al.,* 2011).

In foam floatation technology, bubble size distribution is a major factor determining the surface area of the bubble and also flow pattern of air bubble in gas liquid-system (Chen *et al.,* 1992). Bubble size has also a significant impact on solids removal efficiency because of direct relation of removal rate to surface area and flow pattern of bubble (Chen, 1991). In a typical bubble generator system, bubble size is mostly influenced by air flow rate, pore size of diffuser, and the surface tension of the liquid (Azbel, 1981; Summerfelt, 1999).

Super saturation of water with air and releasing the reserved air can generate numerous small-sized air bubbles, which may have an impact on solid removal efficiency of foam floatation system (Huguenin and Colt, 1989). And efficient removal of fine particles improves nitrification rate (Timmons and Ebeling, 2010), dissolved oxygen (Amirkolaie, 2005) and also reduces the growth of heterotrophic organisms (Leonard *et al.,* 2001). In a similar work, foam fraction efficiency of particulate matter in sea water improved by the use of vacuum air lift (Barrut *et al*., 2013). Therefore, the main objective of this study was to assess the effect of foam floatation unit (skimmer) equipped with a dissolved air flotation reactor on particle collection and bio-filter efficiency in a conventional RAS.

MATERIALS AND METHODS

Experimental System

The experiment was conducted in a 14 m^2 closed room with a height of 2.8 m. To have a stable water temperature, the room temperature was kept at 27˚C using a heater during the experiment. In this study, two different types of air bubble producers were tested: dissolved air flotation reactor (Treatment one) compared to a commercialized air bubble producer in a skimming column (Treatment two). There were two replications for each treatment. A schematic diagram of the first experimental apparatus applied in the current study is shown in Figure 1-a.

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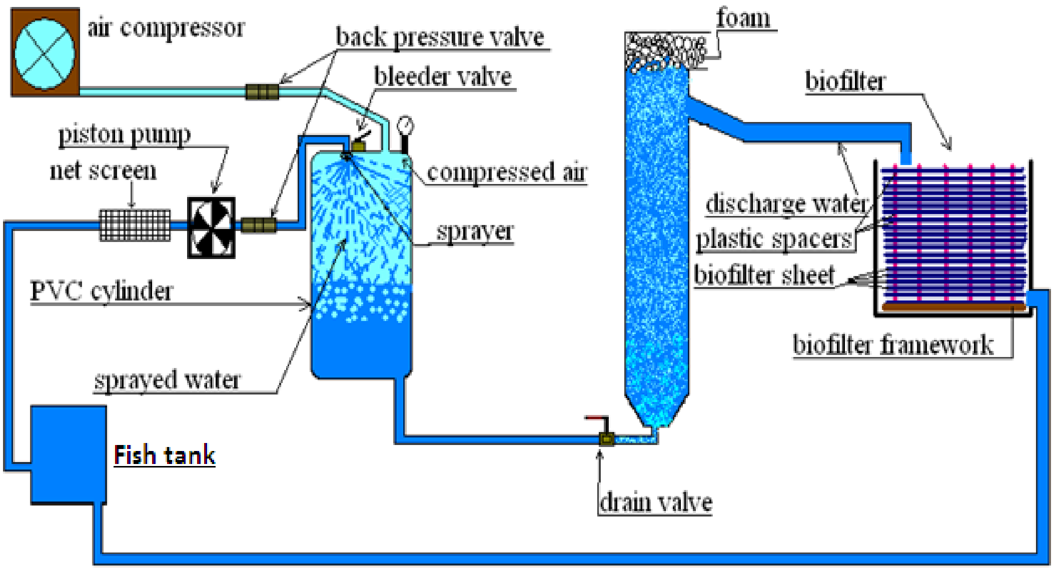
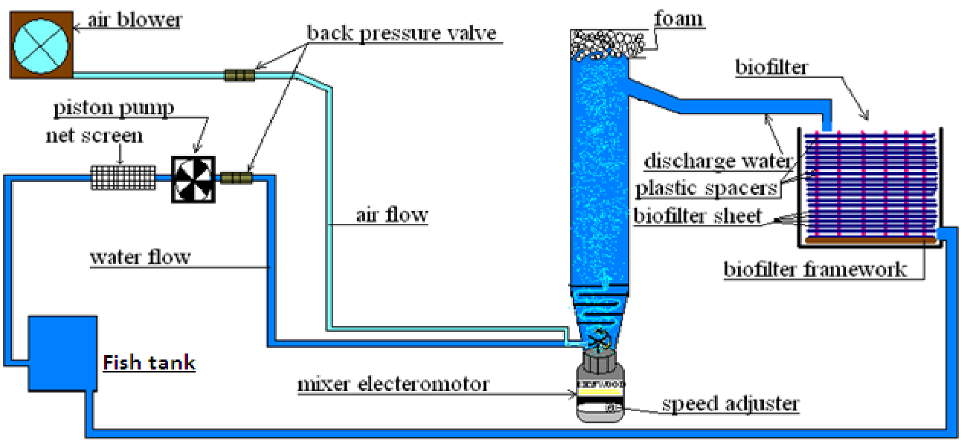


(a)



(b)

Figure 1. Schematic diagram of the two experimental systems: (a) Dissolved air floatation reactor, (b) Commercialized air bubble producer.

This apparatus consisted of an air compressor, PVC cylinder, bio-filter, fish tank, and a piston pump. The air flotation reactor was also equipped with a high PVC bubble column (220 cm) with a 12 cm diameter and 3 mm wall thickness.

In the air flotation system, compressed air was introduced from a compressor through the pressure regulator and flowed into the PVC cylinder. This technology was based on dissolving air in the water under high-pressure and then releasing the air at atmospheric pressure in a wastewater column. This resulted in saturating the pressurized water with air. The released air formed tiny bubbles, which adhered to the suspended matter passed through the wastewater causing the suspended matter to float to the surface of the water making it possible to be removed.

The second system was just a normal skimming system without dissolved air flotation technology. Air flowed using an air blower, passed the pressure regulator valve, and then dispersed through air stones into the PVC column. There was a mixer electromotor (Kenwood, USA) with the rotation of 2000 per minute connected to the bottom of the column in order to generate air flow into the water column. During the experiment, air pressure and water flow rates were adjusted by manually controlled valves and regulators to have similar conditions (flow rate and air pressure) for both treatments. Both skimming columns had a similar calculated hydraulic load of 0.021 cm S^{-1} and a retention time of 6.5 min at water flow rate of 4 L min^{-1}.

Experimental and Analytical Procedures

The experiment lasted for 30 days. There were only two apparatus: one recirculation system equipped with dissolved air flotation reactor and another one equipped with normal air bubble skimmer. Therefore, the study was composed of two consecutive periods and each treatment was replicated once in each period. At the start of each period, the systems were disinfected including bio-filter with 0.5% halamid disinfectant **(**Axcentive SARL, France**)** for 24 hours. Preliminary runs were conducted to activate the bio-filter by addition of 0.5 g d^{-1} ammonia–chloride and 0.5 g d^{-1} sodium-nitrate for a period of 35 days. In the current study, there were no fish in the fish tanks, so ammonia and solid waste excretion by fish were simulated through introduction of ammonium chloride (5 g d^{-1}) and feed powder (Particle size of≤ 40 µm; 300 g d^{-1}), respectively. Feed powder was prepared by grinding a commercial common carp pellet with an estimated gross protein of 330 g kg^{-1}. The amount of ammonium chloride and feed powder were calculated based on ammonia and solid waste excretion by a 200 L fish tank with a stocking density of 75 kg m^{-3} (Timmons and Ebeling, 2010), which was equal to 15 kg fish for a 200 L tank. Both treatments received the same amounts of ammonium chloride and feed powder per day.

Total Ammonia Nitrogen (TAN-N), total Nitrite Nitrogen (NO_2^--N) and total Nitrate Nitrogen (NO_3^--N) were measured every other day at 9:00 hrs by a SAN auto-analyser (Skalar, The Netherlands) during a period of 30 days. Nitrogen concentration was measured at the outlet of the bio-filters. TAN concentration was based on the modified Berthelot reaction with indophenol-blue development, measuring the color intensity at 660 nm. Nitrite-N was diazotized with sulfanilamide while coupling with α-naphtylenediaminedihydrochloride. The reaction produces a reddish purple color, the absorbance of which was measured at 540 nm. Nitrate-N determination was based on reduction of nitrate to nitrite and measured using the same method as for nitrite (Clesceri *et al.,* 1998).

A comparison between the two skimmers to remove the particles was measured by comparing dry matter in the foam discharged from the top of the columns. For the measurement of dry matter, the foam collected from the skimmer was moved into a pre-weighed and pre-dried container and then oven dried at 70°C for 24 hours. Dry matter was calculated by comparing the initial and final weight of the container (ISO 6496 1983).

Statistical Analysis

The system was considered as the experimental unit. Data are presented as means of each treatment with standard deviations. All data were verified for normal distribution of residues before further analysis. To test the effect of different treatments (dissolved air flotation reactor versus normal reactor) on the bio-filter performance and particle removal, the data were tested by the Student's *t*-tests assuming equal variances between the treatments.

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RESULTS

The results of the current study showed that the type of air bubble producer influenced water quality parameters in the recirculation systems (Table 1). Ammonia and nitrite concentrations were lower in the system equipped with air flotation skimmer compared to air bubble system (0.39 and 0.35 mg L^{-1} versus 3.45 and 0.65 mg L^{-1}; $P< 0.05$). However, the type of air bubble producer did not influence nitrate concentration ($P> 0.05$). Total particle collection was recorded higher for air flotation skimmer in comparison to that in the air bubble one (296.1 versus 276.4 g; $P< 0.05$).

Every-other-day measurements of ammonia in the outlet of the bio-filters were almost similar between the two treatments up to day12 of the study (Figure 2-a) and then showed higher values for the air bubble system. While TAN concentration was almost similar for air flotation systems up to the end of the study (0.23-0.44 mg L^{-1}), this parameter reached 12 mg L^{-1} for air bubble system on day 30 of the experiment.

Overall nitrite concentration was lower ($P< 0.05$) in the system equipped with air flotation compared to that in the air bubble during the experimental period. There were no consistent differences between N contents in every-other-day measurement of nitrite-N at the beginning of the study, but this value began to differ distinctively from day 14 of the experiment (Figure 2-b). Nitrite concentration rose to 1.05 mg L^{-1} on day 30 for air bubble system. However, this value reached 0.15 mg L^{-1} for air flotation system on the final day of the experiment.

Data on nitrate concentration throughout the experiment are shown in Figure 2-c. Nitrate concentrations were similar for both treatments at the beginning of the study. However, a larger difference was recorded for nitrate concentration between two treatments on day 30 (475 versus 376 mg L^{-1}).

As demonstrated in Figure 2-d, the quantity of particles collected by skimmer equipped with air flotation was higher at the beginning of the study. However, this quantity was almost similar at the end of the study for both systems.

DISCUSSION

In the current study, a higher removal efficiency of particles in air bubble system was associated with lower concentrations of ammonium and nitrite. These differences in the water quality support the idea that an improvement in particle removal can elevate bio-filter efficiency in RAS.

Although we could not measure air bubble diameter due to technical problems, it is possible that numerous small-sized bubbles produced by air flotation system had a significant effect on bio-filter efficiency. An increase in gas-liquid interface caused by smaller bubble size (Watten and Boyd, 1990; Chen, 1991) leads to the removal of a larger proportion of particles from the system thereby a lower organic matter load on the bio-filter. This finding is in

Table 1. The effect of two different types of air bubble producers (dissolved air floatation reactor versus a commercialized air bubble producer) on water quality parameters.[a]

	Treatment		*P*-value
Parameters	Air flotation	Air bubble	
Ammonia-N (mg L^{-1})	0.39±0.18	3.45±3.79	0.003
Nitrite-N (mg L^{-1})	0.35±0.14	0.65±0.45	0.001
Nitrate-N (mg L^{-1})	243.5±137.6	204.9±105.9	0.581
Total particle collected (g d^{-1})	296.1±0.7	276.4±11.8	0.000

[a] All values are means±standard deviation of 32 measurements which were conducted during a 30-day sampling period.

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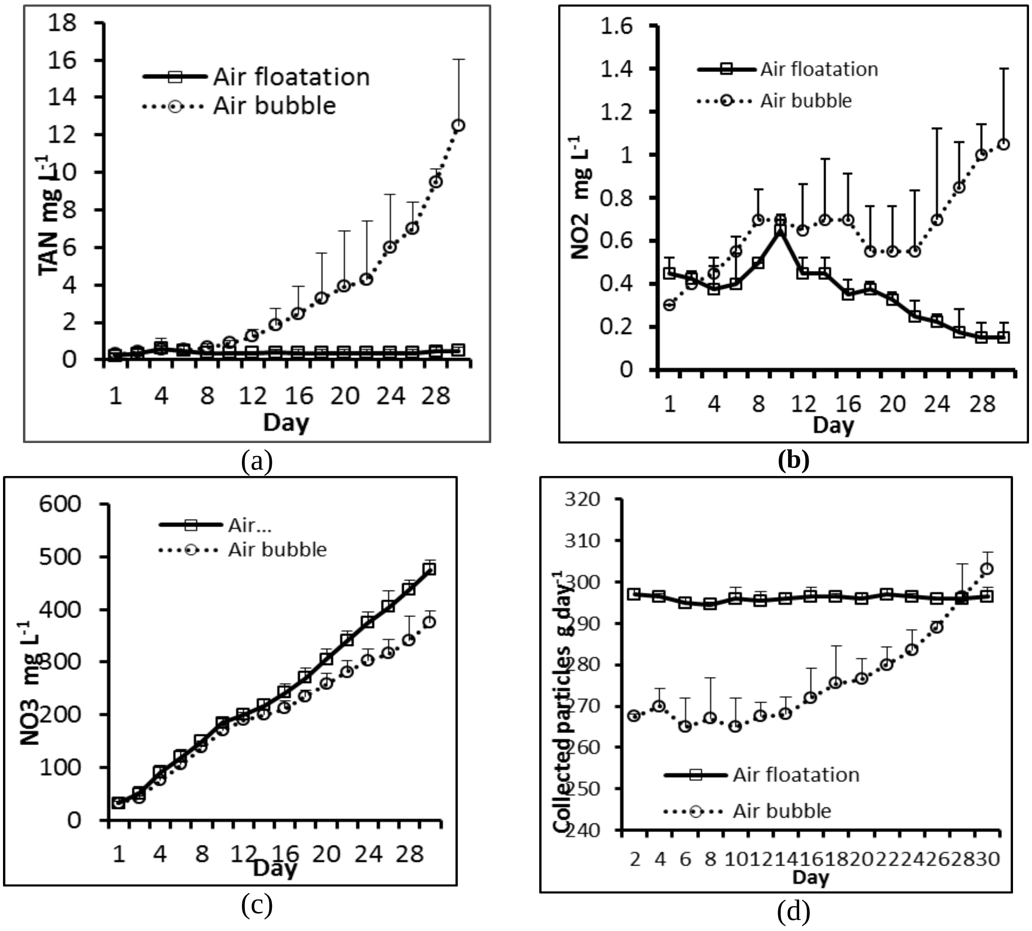

Figure 2. A comparison of Total Ammonium Nitrogen (TAN; a), Nitrite (NO_2; b), Nitrate (NO_3; c) and collected particles (d) in recirculation system as affected by two types of air bubble procedure (dissolved air floatation reactor versus a commercialized air bubble producer).

agreement with the results observed by Huguenin and Colt (1989) who found that bubble size affects removal efficiency of the particles in RAS. There is more evidence showing that bubble size distribution induced by bubble generation system affects particles removal percentage. Chen (1991) concluded that bubble size has a significant impact on solids removal because of its effects on flow patterns and removal rate related to surface volume ratio. Moreover, Timmons and Ebling (2010) observed that creation of a smaller bubble size can maximize foam creation, thereby increasing waste removal in a fractionator. This condition can reduce particle retention on bio-filter media through an improvement in solid waste removal, thereby improving bio-filter efficiency. In addition, a lower particle load can prevent bio-filter clog, thereby a longer bio-filter running time. Larger estimates of particles collected by air flotation system (Table 1) support the idea that lower ammonium and nitrite concentrations in air flotation system in the current study were caused by a lower particle load in the systems, particularly on the bio-filter. Sharma and Ahlert (1977) stated that the dissolved organic matter could promote the growth of heterotrophic organisms that compete for dissolved oxygen and space with nitrifying bacteria. Similarly, Jie *et al.* (2009) showed that nitrification was reduced after supplementation with organic carbon. Furthermore, foam floatation system can remove heterotrophic bacteria (Brambilla *et*

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al., 2008) leading to improved nitrification process.

The average values of TAN for air bubble system were much higher than those of nitrite (3.45 versus 0.65 mg L^{-1}; Table 1). It seems that ammonia-oxidizing bacteria are more sensitive to organic load than nitrite-oxidizing ones. Larger estimates of ammonia may also be caused by consumption of nitrite by denitrification process when the concentration of oxygen is low and organic carbon is enough (Jie *et al.,* 2009). On the other hand, it can be speculated that a lower nitrate accumulation in the air bubble system may indicate the occurrence of denitrification in the system (Figure 2-b). Most of denitrifying micro-organisms are facultative anaerobes and use organic carbon compounds as sources of biosynthetic carbon and electrons (van Rijn *et al*., 2006).

In the present study, TAN and nitrite in the air bubble systems peaked on the final days of the experiment. This further suggests that organic matter accumulation indeed reduced the nitrification process. Figueroa and Silverstein (1992) observed that ammonia removal efficiency decreased by increasing of organic load in the water. Similarly Golz *et al.* (1999) reported that longer solids retention time on the bio-filter reduce the apparent nitrification.

The amount of particles removed by the skimmer increased gradually in air bubble system by the end of the study, but this value was more or less similar for air flotation system (Figure 2-d). A relatively larger efficiency of air bubble skimmer at the end of the study may be related to particle accumulation in the system. This is because a similar amount of particle (300 g d^{-1}) was added to both systems, but a part of the particle (30-40 g d^{-1}) was not removed by the air bubble skimmer. Gradual particle accumulation by the end of the study might have increased particle collection efficiency in the air bubble system. Likewise, observations of Huguenin and Colt (1989) and Summerfelt (1999) showed that foam floatation efficiency was dependent on concentration of solids and that larger solids concentration would lead to a larger removal rate.

CONCLUSIONS

The water quality data from this study indicate that air flotation skimmer can significantly reduce particle concentration by improving particle removal efficiency. This condition has a great impact on the nitrogen concentration of the system. An increase in particle removal efficiency from the system diminishes the amount of organic matter undergoing bacterial decomposition, hence, reducing the organic load discharge into the surrounding environment. Development of a foam floatation system by the use of air flotation technology may play an important role in maintaining water quality in recirculation systems.

REFERENCES

1. Amaro, H. M., Guedes, A. C. and Malcata, F. X. 2011. Advances and Perspectives in Using
2. Microalgae to Produce Biodiesel. *Appl. Ener.,* **88**: 3402-3410.
3. Amirkolaie, A. K. 2005. Dietary Carbohydrate and Fecal Waste in the Nile Tilapia (*Oreochromis niloticus* L.) PhD. Dissertation, Wageningen University, The Netherlands.
4. Amirkolaie, A. K. 2011. Reduction in the Environmental Impact of Waste Discharged by Fish Farms through Feed and Feeding. *Rev. Aqua.,* **3**, 19-26.
5. Azbel, D. 1981. *Two-Phase Flows in Chemical Engineering.* Cambridge University Press, Cambridge, 311 PP.
6. Barruta, B., Blancheton, J. -P, Callier, M., Champagnec, J. Y. and Alain Grasmick, A. 2013. Foam Fractionation Efficiency of a Vacuum Airlift Application to Particulate Matter Removal in Recirculating Systems. *Aqua. Eng.,* **54** : 16-21.
7. Braaten, B., Poppe, T., Jacobsen, P. and Maroni, K. 1986. Risks from Self-Pollution in Aquaculture: Evaluation and

[DOR: 20.1001.1.16807073.2018.20.2.4.8]

Consequences. In: "*Efficiency in Aquaculture Production: Disease and Control*", (Eds.): Grimaldi, E. and Rosenthal, H. *Proceeding of the 3rd International Conference on Aquafarming 'Aquaculture'86'*, Oct. 9-10, 1986, Verona, Italy, PP. 139-165.
8. Brambilla, F., Antonini, M., Ceccuzzi, P., Terova, G. and Saroglia, M. 2008. Foam Fractionation Efficiency in Particulate Matter and Heterotrophic Bacteria Removal from a Recirculating Seabass (*Dicentrarchus labrax*) System. *Aqua. Eng.*, **39**: 37-42.
9. Chen, S. 1991. Theoretical and Experimental Investigation of Foam Separation Applied to aquaculture. PhD. dissertation, Cornell University, Ithaca, NY, 239 PP.
10. Chen, S., Timmons, M. B., Bisogni, J. J. and Aneshansley, D. J. 1992. Suspended Solids Removed by Foam Fractionation. *Prog. Fish. Cult.*, **55**: 69–75.
11. Chen, C. Y., Yeh, K. L., Aisyah, R., Lee, D. J. and Chang, J. S. 2011. Cultivation, Photo Bioreactor Design and Harvesting of Microalgae for Biodiesel Production: A Critical Review. *Bioresour. Technol.*, **102**: 71-81.
12. Clesceri, L. S., Greenberg, A. E. and Eaton, A. D. 1998. *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association, Washington, 1325 PP.
13. Cripps, S. J. and Bergheim, A. 2000. Solids Management and Removal for Intensive Land-Based Aquaculture Production Systems. *Aqua. Eng.*, **22**: 33-56.
14. FAO (Food and Agriculture Organization of the United Nations). 2012. *The State of World Fisheries and Aquaculture*. FAO, Rome.
15. Figueroa, L. A. and Silverstein, J. 1992. The Effect of Particulate Organic Matter on Biofilm Nitrification. *Water. Environ. Res.*, **64**: 728-733.
16. Golz, W. J., Rusch, K. A. and Malone, R. F. 1999. Modelling the Major Limitations on Nitrification in Floating-Bead Filters. *Aqua. Eng.*, **20**: 43-61.
17. Huguenin, J. E. and Colt, J. 1989. *Design and Operating Guide for Aquaculture Seawater System*. Elsevier, Amsterdam, 264 PP.
18. ISO. 1983. *Animal Feeding Stuffs: Determination of Moisture Content*. ISO 6496, International Organization for Standardization, Geneva, Switzerland.
19. Jie, H., Daping, L., Qiang, L., Yong, T., Xiaohong, H., Xiaomei, W., Xudong, L. and Ping, G. 2009. Effect of Organic Carbon on Nitrification Efficiency and Community Composition of Nitrifying Biofilms. *J. Environ. Sci.*, **21:** 387-394.
20. Klontz, W., Stewart, B. C. and Eib, D. W. 1985. On the Etiology and Pathophysiology of Environmental Gill Disease in Juvenile Salmonids. In: "*Fish and Shellfish Pathology*", (Ed.): Ellis, A. E. Academic Press, London, PP. 199-210.
21. Kruner, G. and Rosenthal, H. 1987. Circadian Periodicity of Biological Oxidation under Three Different Operation Conditions. *Aqua. Eng.*, **6**: 79-96.
22. Leónard, N., Guiraud, J. P., Gasset, E., Cailleres, J. P. and Blancheton, J. P. 2001. Bacteria and Nutrients Nitrogen and Carbon in a Recirculating System for Sea Bass Production. *Aqua. Eng.*, **26**:111–127.
23. Park, J., Kim, Y., Kim, P. -K. and Daniels, H. V. 2011. Effects of Two Different Ozone Doses on Seawater Recirculating Systems for Black Sea Bream *Acanthopagruss chlegeli* (Bleeker): Removal of Solids and Bacteria by Foam Fractionation. *Aqu. Eng.*, **44**: 19-24.
24. Piedrahita, R. H. 2003. Reducing the Potential Environmental Impact of Tank Aquaculture Effluents through Intensification and Recirculation. *Aqua.*, **226**: 35-44.
25. Rawat, I., Ranjith Kumar, R., Mutanda, T. and Bux, F., 2011. Dual Role of Microalgae: Phycoremediation of Domestic Wastewater and Biomass Production for Sustainable Biofuels Production. *Appl. Ener.*, **88**: 3411-3424.
26. Sharma, B. and Ahlert, R. C.1977. Nitrification and Nitrogen Removal. *Water. Res.*, **11**: 897-925.
27. Summerfelt, S. T. 1999. Waste handling Systems. In: "*CIGR Handbook of Agricultural Engineering: Animal Production and Aquacultural Engineering*", (Eds.): Bartali, E. H. and Wheaton, F. W. American Society of Agricultural Engineers, St. Joseph, MI, **II:** 309-350.
28. Suzuki, Y., Hanagasaki, N., Furukawa, T. and Yoshida, T. 2008. Removal of Bacteria from Coastal Seawater by Foam Separation Using Dispersed Bubbles and Surface-Active Substances. *J. Biosci. Bioeng.*, **105**: 383-388.

29. Timmons, M. B. and Ebeling, J. M. 2010. Recirculating Aquaculture. 2nd Edition, Cayuga Aquaculture Ventures, Ithaca, NY, USA, 948 PP.
30. Twarowska, J. G., Westerman, P. W. and Losordo, T. M. 1997. Water Treatment and Waste Characterization Evaluation of an Intensive Recirculating Fish Production System. *Aqua. Eng.*, **16**: 133-147.
31. Van Rijn, J., Tal, Y., Schreier, H. J., 2006. Denitrification in Recirculating Systems: Theory and Applications. *Aquacult. Eng.* **34:** 364-376.
32. Watten, B. J. and Boyd, C. E.1990. Gas Transfer within a Multi-Stage Packed Column Oxygen Absorber: Model Development and Application. *Aqua. Eng.*, **9**: 33-59.

بهبود کارآیی سیستم جمع آوری با کف با راکتور هوای شناور محلول

م .صادقی، ع. کرامت امیرکلایی، و ح. اورجی

چکیده

تکنولوژی جمع آوری با کف به منظورجمع آوری ذرات ریز در سیستم مداربسته آبزیان ابداع شده است. هدف اصلی این تحقیق بررسی اثرات راکتور هوای محلول بر کارآیی دستگاه جمع آوری با کف (اسکیمر) در یک مدار بسته آبزیان می باشد. در این آزمایش دو نوع حباب ساز متفاوت بمدت ۳۰روز مورد آزمایش قرار گرفت: راکتورحباب سازی هوای محلول با حباب ساز تجاری در یک ستون اسکیمر مورد مقایسه قرار گرفت. میزان تراکم نیتروژن و جمع آوری ذرات با کف یک روز در میان در این تحقیق اندازه گیری شدند. نتایج آزمایش نشان داد که غلظت آمونیوم و نیتریت در تیمار مجهز به اسکیمر هوای محلول بصورت محسوسی نسبت به تیمار حباب هوا تجاری کمتر است (۰.۳۹ و ۰.۳۵درمقایسه با ۳.۴۵ و ۰.۶۵؛ **P < 0.05**). ولی غلظت نیترات در این تحقیق تحت تاثیر نوع سیستم های جمع اوری با حباب قرار نگرفت(**P > 0.05**). اندازه گیری یک روز در میان نشان داد که میزان تراکم نیتروژن در بین دو تیمار تا روز ۱۵آزمایش تقریبا مشابه بوده و بعداز آن غلظت های بالاتری برای سیستم مجهز به راکتور حباب ساز تجاری مشاهده شده است. میزان جمع آوری ذرات مواد آلاینده در تیمار حباب ساز هوای محلول بطور محسوسی بیشتر از تیمار دوم بوده است (۲۹۶.۱ در مقایسه با ۲۷۶.۴ **:P < 0.05**)، اگرچه میزان جمع آوری روزانه ذرات در انتهای دوره برای هر دو سیستم تقریبا یکسان بود. در نتیجه گیری میتوان گفت که اسکیمر هوای محلول با افزایش جمع آوری ذرات باعث بهبود کیفیت آب در یک سیستم مدار بسته می شود.

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