INFLUENCY OF AMMONIUM NITROGEN CONCENTRATION AND AERATION TIME ON POULTRY SLAUGHTERHOUSE WASTEWATER NITRIFICATION PROCESS

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1 INTRODUCTION

With regard to pollution control, removal of excess nitrogen from wastewater is necessary because reduced forms of nitrogen consume dissolved oxygen of receiving water bodies (Azevedo Neto, 1998). Another consequence of release wastewater containing large amounts of nutrients is the overgrowth of algae and aquatic plants, causing eutrophication (Jeon and Park, 2000).

Nitrogenous compounds can be removed from wastewater using physical-chemical or biological processes. Conventionally, biological processes are used to remove nitrogenous compounds from wastewater and occur in three stages: ammonification, which includes the conversion of organic nitrogen to ammoniacal nitrogen; nitrification, in which ammonia is oxidized to nitrite and subsequently to nitrate; and lastly, denitrification, where oxidized forms of nitrogen are reduced to nitrogen gas (Metcalf and Eddy, 2003).

The nitrification occurs under aerobic conditions by two groups of chemoautotrophic bacteria called ammonium oxidizers and nitrite oxidizers (Philips et al., 2002). As the efficiency of oxidation reactions is low, the nitrifying organisms have a slow growth rate, requiring a long retention time cell allowing for the development of micro-organisms and ensuring the permanence of nitrifying biomass in the reactor. Therefore, the nitrification is considered the limiting step in processes of nitrogen removal in biological systems (Garbossa, 2006).

It should be noted that the nitrification process is not capable to remove nitrogen from wastewater, it just change the oxidation state, since the reaction products are soluble nitrogenous compounds (Ono, 2007). For the effective removal of nitrogen, nitrate must be reduced to nitrogen gas (N_2), a process carried out by denitrifying organisms that need anoxic conditions and an external carbon source (Franchin, 2006).

Hence, this study aimed to evaluate the influence of the aeration time and ammonia nitrogen concentration in the nitrification process of poultry slaughterhouse wastewater using a sequential batch reactor (SBR), with the biomass immobilized in polyurethane foam.

2 MATERIALS AND METHODS

2.1 Poultry slaughterhouse wastewater

The poultry slaughterhouse wastewater was collected at the exit of an anaerobic pond. The samples were collected and preserved as recommended by NBR 9898/1987.

2.2 Sequential batch reactor

The sequential batch reactor (SBR) was operated at laboratory-scale, with a work volume of 3.5 L, in a cylindrical shape of polyethylene internally coated with polyurethane foam of 1cm thickness used to promote nitrifying biomass growth in a mixed form (suspended or attached).

The aeration system consisted of an aquarium aerator coupled to a flow meter to control the intake air flow, adjusted to 3.0 L min^{-1} (Qin and Liu, 2006), with the spread of air made by two porous stones.

The SBR was operated in the following phases: feeding (instantaneous): wastewater was added to the batch remaining in the reactor, in which the biomass was suspended; aeration stage (7, 9.5 and 12 h): air supply (3.0 L min^{-1}) for the required conversion of N-NH_4^+-N to NO_2^- and subsequently to N-NO_3^-; sedimentation (30 minutes): sedimentation of solids and clarification of the effluent to be discharged; discharge (10 minutes): the removal of clarified effluent, while 20% of the volume was maintained as initial inoculum for the next batch; rest/analysis (80 minutes): analysis of ammonia-N for adjusting the initial concentration for next batch.

Samples were collected at the beginning of the aerobic phase and after the sedimentation step, and were analyzed the following parameters: ammonia-N, COD, pH and alkalinity. Prior to analysis, samples were centrifuged at 5000 rpm for 10 minutes (Fontenot et al., 2007).

2.3 Experimental design and statistical analysis

The experiment was conducted in three stages of aeration (7, 9.5 and 12 h) and three ammonium nitrogen concentrations (80, 100 and 120 mg L^{-1}), configured in a 3^2 factorial design with 36 trials, which is the result of the combination of nine treatments with four replications. The response analyzed was the $N\text{-}NH_4^+$ oxidation.

The software Statistica for Windows version 8.0 was used to generate the mathematical model, to determine the regression coefficient (R^2), to perform the variance analysis and build the response surface to evaluate the effects of independent variables on the response examined, with a significance level of 5%.

From the results of 36 trials obtained by combining the levels of the two factors studied, aeration time (AT) and ammonium nitrogen ($N\text{-}NH_4^+$), it was attempted to identify the best conditions to evaluate the nitrification process, analyzing as a response the $N\text{-}NH_4^+$ oxidation efficiency. For this analysis we used a second order mathematical model, where the response is described in terms of significant variables.

3 RESULTS AND DISCUSSION

3.1 Efficiency of N-NH4+ oxidation

Figure 1 shows the estimated linear and quadratic effects, and interaction between factors studied in the level of 95% confidence.

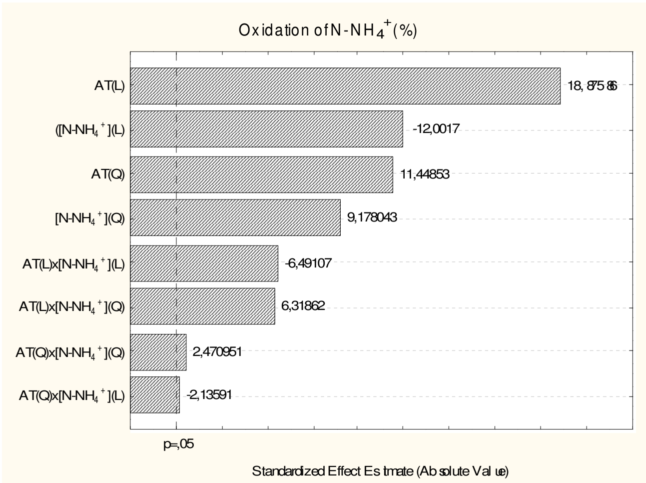

FIGURE1 **Linear and quadratic effects estimative of independent variables (AT and $N\text{-}NH_4^+$ concentration) on $N\text{-}NH_4^+$ oxidation efficiency.**

It can be seen from Figure 1 that the linear and quadratic effects of the two factors, time of aeration and $N\text{-}NH_4^+$ concentration, and all linear and quadratic interactions between them were statistically significant for the efficiency of $N\text{-}NH_4^+$ oxidation. From the estimation of significative effects, a polynomial equation of second order (Eq. 1) was obtained to establish a predictive mathematical model of response.

$$N\text{-}NH_4^+ \text{ oxidation (\%)} = 72{,}00 + 13{,}23(AT) + 6{,}95(AT)^2 - 8{,}41[N\text{-}NH_4^+] + 5{,}57([N\text{-}NH_4^+])^2 - 5{,}57AT\text{x}[N\text{-}NH_4^+] + 4{,}70AT\text{x}([N\text{-}NH_4^+])^2 - 1{,}59(AT)^2\text{x}[N\text{-}NH_4^+] + 1{,}59(AT)^2\text{x}([N\text{-}NH_4^+])^2 \quad \text{Eq. (1)}$$

The quadratic model for $N\text{-}NH_4^+$ oxidation showed a determination coefficient (R2 = 0.9677) that means that 96.77% of $N\text{-}NH_4^+$ oxidation efficiency variation are explained by the model.

The answer surface methodology (Figure 2) revealed that simultaneous behavior of two independent variables, and the determination of regions of maximum efficiency in $N\text{-}NH_4^+$ oxidation occurred.

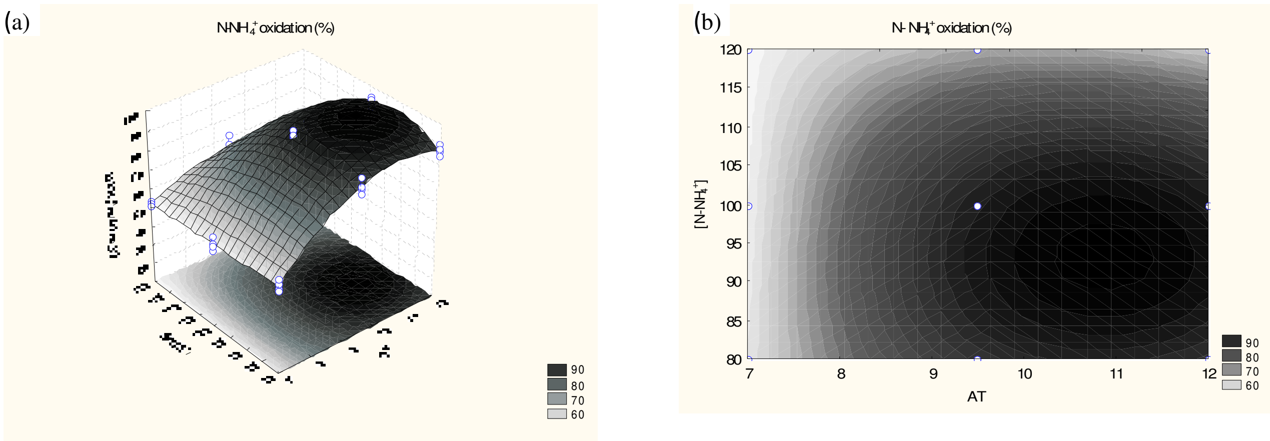

FIGURE2 **Answer surface (a) and level curves (b) in function of AT and N-NH_4^+ concentration, to the variable answer N-NH_4^+ oxidation.**

The Figure 2 shows that a maximum efficiency in N-NH_4^+ oxidation between 87 and 92% occurred in the AT range from 9.5 to 12 hours at a N-NH_4^+ concentration was between 80 and 100 mg L^{-1}. Moreover, the N-NH_4^+ oxidation efficiency was higher as AT increased and N-NH_4^+ concentration decreased. When the AT in the study was about 7 h, at any N-NH_4^+ concentration, the N-NH_4^+ oxidation efficiency was around 50%. If the N-NH_4^+ concentration amounted to120 mg L^{-1}, N-NH_4^+ the oxidation efficiency reached from 60 to 70% relative to the performance obtained at the AT ranging from 9,5 to 12 h..

Isoldi et al. (2005) evaluated the performance of a combined system, a UASB/aerobic reactor, in terms of efficiency of simultaneous removal of COD and nitrogenous compounds in parboiling rice wastewater. The hydraulic detention time (HDT) in the aerobic reactor where nitrification occurred was about 15 h, with a 49.6 mg L^{-1} of feeding N-NH_4^+ concentration and an average removal efficiency of 87%. In this study, results were more satisfactory for N-NH_4^+ oxidation considering that initial N-NH_4^+ concentration (80 and 100 mg L-1) was higher and aeration time was lower (9.5 to 12 h).

3.2 pH and alkalinity behavior

The Figures 3 (a) and 3 (b) show the behavior of pH and alkalinity during nitrification process in all experiments.

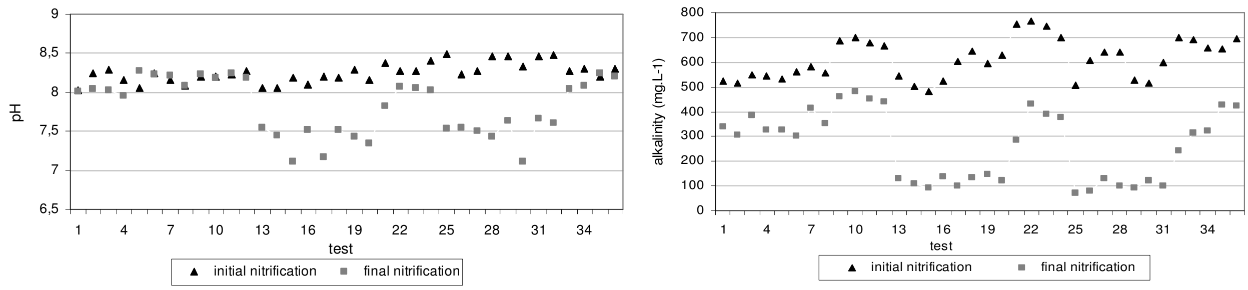

FIGURE3 **pH (a) and alkalinity (b) behavior during nitrification process**

Figure 3 (a) shows that during the nitrification process in all trials, the pH ranged between 7.0 and 8.5. These values are within the range established by Metcalf and Eddy (2003) that are between 7.0 and 9.0, considered ideal for maintenance of vital functions of nitrifier bacterias. Lower values may lead to nitrification inhibition. In almost experiments, the expected pH behavior and a decrease thereof during the process was found, given that a H^+ ions formation and consequently a decrease of the pH occur.

It can be observed from Figure 3 (b) that all experimental runs showed a decrease in the alkalinity amount, which was expected since during N-NH_4^+ oxidation alkalinity is consumed. Among the experiments 13 to 20 and 25 to 32, corresponding to 9.5 and 12h AT and N-NH_4^+ concentrations of 80 and 100 mg L^{-1} respectively, the lowest values of alkalinity at the end of nitrification were found. As already discussed, these tests were those with the highest N-NH_4^+ oxidation efficiencies.

4 CONCLUSIONS

- The reactor SBR performed well in the nitrification process, showing efficient N-NH4+ oxidation of poultry slaughterhouse wastewater;
- The results showed that both AT and N-NH4+ concentration had a significant influence, with an interval of 95% on N-NH4+ oxidation efficiency;
- More satisfactory results were obtained with AT between 9.5 and 12 h, and N-NH4+ concentration between 80 and 100 mg L-1. In these experimental runs, N-NH4+ oxidation efficiency was between 87 and 92%;
- The parameters pH and alkalinity showed the expected behavior during the process.

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