QUICK START-UP OF DEAMMONIFICATION PROCESS USING NITRAMMOX® REACTOR

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ABSTRACT: Among the processes for autotrophic nitrogen removal, the deammonification process stands out for achieving high efficiency in the treatment of effluents with low C/N ratio, such as swine digestate. Although several studies have been developed in recent years, there are still some challenges related to the start-up of the deammonification process using digestates instead of synthetic wastewaters. The aim of this work was to evaluate the start-up of a single process of deammonification using digestate from a covered lagoon biodigester (CLB) in the NITRAMMOX® reactor. This reactor was designed to work in continuous flow, and is of airlift type with concentric tubes, agitated and mixed pneumatically. Additionally, the reactor is designed to itself geometry of dimensioning with conical bottom to favor the two groups of deammonification bacterias: the ammonia oxidizing bacteria (AOB) and the Anammox bacteria. After inoculation, the NITRAMMOX® reactor achieved the start-up close to the tenth day with nitrogen removal average up to 70% in the first 30 days of operation. In addition, it was also noted that NITRAMMOX® can be used as a reactor for the deammonification process using digestate from a CLB as a substrate, contributing in this way with the management of the wastes generated in the swine chain, which refer to large volumes of significant pollutant potential.

Keywords: swine digestates, biological nitrogen removal, ammonium wastewater treatment.

INTRODUCTION

The current way of swine production, termed concentrated animal feeding operations (CAFOs), brings with it some problems to the environmental and public health due to some characteristics of the effluents generated in that, related to the high concentration of organic matter, nutrient, pathogens and antibiotics. The application of these effluents as soil fertilizer had a measurable effect on surface and groundwater quality, and promotes higher concentrations of total nitrogen when compared to control watersheds (CHRISTENSON; SERRE, 2017). The anaerobic digestion (AD) is the common way applied to treat the swine manure, where the organic matter present in the effluent is stabilized by decomposition in the absence of molecular oxygen. However, this kind of treatment do not allow for nutrients removal, like ammoniacal nitrogen, that remains in the liquid fraction resulted from the treatment (AMINI et al., 2017).

Due to the high amount of nitrogen, the digestate must be treated aiming to reduce the pollutant potential and to comply the guidelines and agro-environmental rules. Among the types of treatment that can be applied for nitrogen removal the combination of partial nitritation with the anaerobic ammonium oxidation (Anammox) process (PN/A), that is also known as deammonification, have brought some advantages compared to other available technologies. PN/A do not require an external source of organic carbon and promote reduction in energy costs and sludge production (NAWI; STUCKEY, 2018). The PN/A process includes the oxidation of approximately half of the ammonium present in digestates to nitrite, by the ammonium oxidizing bacteria (AOB), followed by the conversion of the remaining ammonium and nitrite to N_2, by the Anammox bacteria (MIAO et al., 2018).

Considering the unstable characteristics of the swine manure and different seasonal conditions during the operation of reactors, the efficiency AD in covered lagoons biodigesters (CLB) can change and consequently the digestate composition, mainly concencentrations of organic carbon and ammoniacal nitrogen will be different. This variation in digestate composition represents one of the major challenges to the practical application of PN/A process to this kind of wastewater, due to the high sensitivity of anammox bacteria to different environmental conditions and its very low growth rates (around 11 days). Therefore the start-up period of this kind of process usually could take more time than other biological processes (WANG et al., 2017).

To overcome the challenges coupled with the effluents treatment for nitrogen removal, recently a different reactor was developed (EMBRAPA, 2018). The NITRAMMOX® reactor is a new proposal of pneumatic reactor with intrinsic features projected to remove nitrogen from effluents with low C/N ratio, like swine digestates. Therefore, the purpose of this study was to evaluate the start-up and stable operation of the PN/A process in a single reactor called NITRAMMOX®, operating with digestate coming from a CLB.

MATERIAL AND METHODS

This study was developed in Laboratory of Studies and Environmental Analysis (LEEA) of Embrapa Suínos e Aves located in Concórdia, SC.

The NITRAMMOX® reactor was developed to operate in a single phase and based in the concept of airlift reactor coupled to a three-phase separator used in UASB reactors. This reactor has a total net volume of 8 L and operates with continuous feed, recirculation and pneumatic homogenization. Inside the reactor there is a concentric tube to favor both microbial groups with aerobic and anaerobic zones, wherein the digestate is moved from bottom-up (riser) by the displacement of air bubbles that are fed in the base of the reactor (this phenomenon favors the AOB). The fluid returns from up-bottom in a different region than the rise (downcomer) (which favors the anammox bacteria). The experimental system is shown in Figure 1.

The anammox biomass used to inoculate the NITRAMMOX® reactor was deposited under the provisions of the Collection of Microorganisms of Interest for Swine and Poultry (CMISEA) at Concórdia (accession number: BRMSA 00323). The biomass was previously acclimated in a continued flow reactor with synthetic wastewater containing 100 mg NH_3-N L^{-1} e 100 mg NO_2^--N L^{-1}. In case of the AOB, they were also maintained at Embrapa and were harvesting from a sequencing batch reactor fed with synthetic wastewater containing 300 mg NH_4-N L^{-1} (VIANCELLI et al., 2011; DE PRÁ et al., 2016). The total cellular concentration of AOB + Anammox used to inoculate the reactor was 2.38 gVSS L^{-1}, obtained by the ratio of wet biomass of 0.3:1 L AOB:ANAMMOX in 8 L of reactor.

The initial characteristics of the CLB digestate used to fed the reactor was 1192 mg L^{-1} of NH_3-N and 176 mg L^{-1} of total organic carbon (TOC), which provides a C/N ratio of approximately 0.15. For the start-up of the reactor, the digestate was diluted to a concentration of 100 mg L^{-1} NH_3-N and according to the hydrodynamic characterization of the NITRAMMOX® obtained by De Prá (2017) the nitrogen loading rate (NLR) was maintained in 0.5 kg-N m^{-3} d^{-1}, flow rate of 32 L d^{-1} and recirculation flow of 64 L d^{-1}. The Hydraulic Retention Time (HRT) was fixed at 6 h and temperature between 26 and 35 ºC. The system was also maintained with continuous aeration regulated according to the stoichiometric coefficients obtained.

Samples were collected daily from the reactor influent and effluent to follow-up the start-up process inside the NITRAMMOX®. Determinations of NH_3-N NO_2^--N and NO_3^--N were performed by specific flow injection analysis methods for each parameter, adapted from Standard Methods (APHA, 2012). Dissolved oxygen (DO) and pH were analyzed using pHmeter and DOmeter, respectively.

RESULTS AND DISCUSSION

The enrichment of anammox and AOB sludge previously in the lab-scale reactors is a good strategy for fast start-up of the single-stage deammonification system, as observed by Casagrande et al. (2013).

Both sludges were enriched before the NITRAMMOX® reactor inoculation, and the start-up was monitored for 30 days, as shown in Figure 2(a), during which the influent ammoniacal nitrogen concentration was kept stable in approximately 100 mg L^{-1} and the airflow varied according to the concentration of nitrite in the effluent to enable PN. To start-up the deammonification process it is primordial to keep low DO concentration, once this is helpful for the activation of anammox bacteria that present higher doubling time than AOB. It also helps to reduce the possibility of nitrite inhibition due to the maintenance of the aerated environment (YANG et al., 2019).

Figure 2(a) shows the concentration of the nitrogen forms in the influent and effluent, where it is possible to see that during the start-up of the NITRAMMOX® milder nitrogen concentration conditions was applied and NLR of approximately 0.5 kg-N m^{-3} d^{-1} to promote the activity of microorganisms of interest. These conditions where based on those previously applied by de Prá et al. (2013), and it is possible to note that after 10 days the stoichiometric coefficients obtained get approximated to the theoretical values (Figure 2(b)) and the nitrogen removal efficiency was about 60% (Figure 2(a)). This period was the same to the obtained by Yang et al. (2019) to start-up the deammonification, which also applied NLR of approximately 0.5 kg-N m^{-3} d^{-1} initially, and similar to the obtained by De Prá (2017) using the NITRAMMOX® fed with swine digestate coming from a UASB reactor (12 days).

It was possible to observe that after a period of biomass adaptation of approximately 8 days, the concentration of NH_3-N, NO_2^--N and NO_3^--N were significantly reduced at reactor effluent, demonstrating the gradual interaction and increased activity of the bacteria responsible for the deammonification process. After the 13th operation day the air flow supplied was increased aiming to get higher nitrogen removal efficiency due to increasing partial nitration and consequently nitrite and ammonia supply to anammox bacteria. However, as can be observed at Figure 2(a), at this moment the efficiency was reduced and get inconstant, probably due to the relatively long doubling time of the Anammox bacteria. However, although the observed fall in efficiency, after a few days the process was reestablished, with the increasing of nitrogen removal efficiency. This information indicate the restoration of the bacterial activity to the air flow, and by the 25th day the process of deamonification get stable again giving rise to a future increase in the concentration of ammoniacal nitrogen fed to the NITRAMMOX®.

CONCLUSION

The NITRAMMOX® reactor proved to be a promising technology for the nitrogen removal of swine digestate, with start-up around 10 days and robust for the applicability of the deamonification process, supporting a wide operational variability and adapting well to varied situations.

With controlled conditions of temperature (between 26 and 35 ºC), HRT (6 hours) and initial ammonia concentration around 100 mg L^{-1} in the CLB digestate, the NITRAMMOX® reached 70% of nitrogen removal efficiency in 30 days.

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REFERENCES

AMINI, A. et al. Cost-effective treatment of swine wastes through recovery of energy and nutrients. **Waste Management**, v. 69, p. 508-517, 2017.

APHA – American Public Health Association. **Standard methods for the examination of water and wastewater**. 22 ed. Washington, DC: American Public Health Association. 2012.

CASAGRANDE et al. High nitrogen removal rate using ANAMMOX process at short hydraulic retention time. **Water science & Technology**, v. 67, n. 5, p. 968-975, 2013.

CHOI et al. Key operating parameters affecting nitrogen removal rate in single-stage deammonification. **Chemosphere**, v. 207, p. 357-364, 2018.

CHRISTENSON, E. C.; SERRE, M. L. Integrating remote sensing with nutrient management plans to calculate nitrogen parameters for swine CAFOs at the sprayfield and sub-watershed scales. **Science of The Total Environment**, v. 580, p. 865-872, 2017.

DE PRÁ, M. C. Desenvolvimento e validação de protótipo de reator para aplicação do processo de desamonificação utilizando digestato da suinocultura. 2017. Tese (Doutorado em Engenharia Química), UFSC, Universidade Estadual de Santa Catarina, Florianópolis, 2017.

DE PRÁ, M. C. et al. Kinetic models for nitrogen inhibition in ANAMMOX and nitrification process on deammonification system at room temperature. **Bioresource Technology**, v. 202, p. 33-41, 2016.

DE PRÁ, M. C. et al. Influência da concentração de nitrogênio em reatores com atividade anammox durante o start-up do sistema. **III Simpósio Internacional sobre Gerenciamento de Resíduos Agropecuários e Agroindustriais**, n. 2, p. 12-15, 2013.

Empresa Brasileira De Pesquisa Agropecuária. EMBRAPA. No. processo: 913209929. Title: NITRAMMOX.

KHAN et al. Long-term efficient deammonification operation with PVA/alginate carrier modified by foaming agente. International **Biodeterioration & Biodegradation**, v. 129, p. 148-155, 2018.

MIAO, Y. et al. Partial nitrification-anammox (PNA) treating sewage with intermittent aeration mode: Effect of influent C/N ratios. **Chemical Engineering Journal**, v. 334, p. 664-672, 2018.

NAWI, M. N. M.; STUCKEY, D. C. Pre-oxidation of ammonium using nanofiltration membranes for partial nitrification preceding Anammox. **Chemical Engineering Journal**, v. 353, p. 218-224, 2018.

VIANCELLI, A. et al. Bacterial biodiversity from an anaerobic up flow bioreactor with ANAMMOX activity inoculated with swine sludge. **Brazilian Archives of Biology and Technology**, v. 54, n. 5, p. 1035-1041, 2011.

WANG, G. et al. A pilot-scale study on the start-up of partial nitrification-anammox process for anaerobic sludge digester liquor treatment. **Bioresource Technology**, v. 241, p. 181-189, 2017.

YANG et al. Quick start-up and stable operation of a one-stage deammonification reactor with a low quantity of AOB and ANAMMOX biomass. **Science of The Total Environment**, v. 654, p. 933-941, 2019.

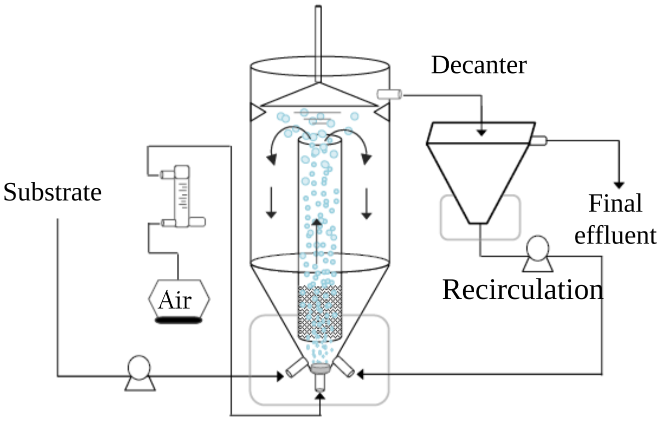

Figure 1. Schematic representation of the experimental system of the NITRAMMOX® reactor (DE PRÁ, 2017).

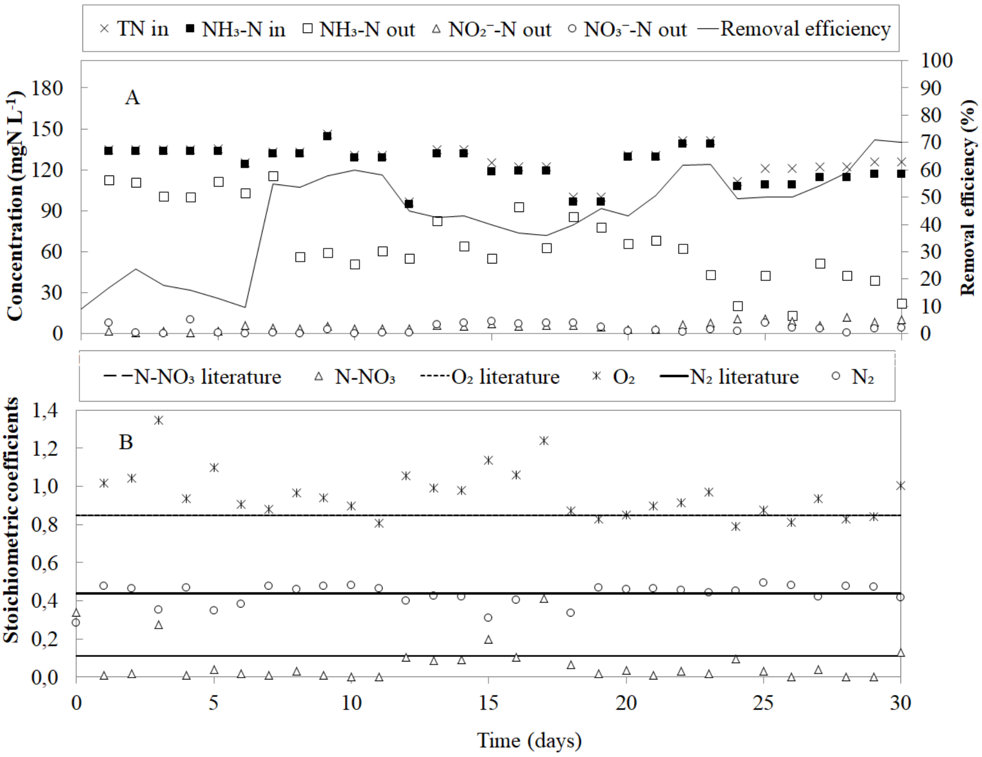

Figure 2. Performance of the NITRAMMOX® reactor: A – Monitoring of concentrations of nitrogen species and B – Monitoring of the stoichiometric coefficients.