EFFECT OF NITROGEN LOADING RATE ON DIGESTATE TREATMENT BY DEAMMONIFICATION PROCESS

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ABSTRACT: Deammonification is being studied as an alternative for digestate treatment to remove ammoniacal nitrogen. In this process, the ammonia is partially oxidized to nitrite, and both species, NO_2^--N and NH_4^+-N, are substrate to anammox process, under autotrophic conditions. The concentration of ammoniacal nitrogen in effluents is an important key to be controlled in this process to avoid overloading that could be deleterious to anammox bacteria. The present study aimed to test the effect of nitrogen loading rate (NLR) over the deammonification process in an EGSB reactor. It could be concluded that digestate treatment by deammonification process is feasible with nitrogen removal efficiency higher than 80% for a NLR of 2.5 kg m^{-3} d^{-1}.

Keywords: anammox; partial nitration; ammoniacal nitrogen; wastewater treatment.

INTRODUCTION

Swine farming stands out as a productive chain of great economic and social importance, especially in the southern region of Brazil. Thus, in order to increase productivity and to have greater sanitary control, subsistence model goes to larger concentrated animal feeding operations (CAFOs) in small territorial areas. However, this production model generates high effluent volumes (Kunz, Miele e Steinmetz, 2009). Thus, swine manure has high concentration of nitrogen, organic matter and other pollutants which exceeds land assimilation capacity arising the need to reduce the negative impacts over the environment.

The organic matter can be considerably reduced by anaerobic digestion (AD) process (Amaral *et al.*, 2016). However, the nitrogen is not removed in this process and an additional treatment is required to reduce this nutrient in digestate (AD effluent). An alternative to treat the nitrogen is the deammonification process (Chini *et al.*, 2016). Deammonification is a consortium of anammox and nitrifying bacteria. Initially, occurs the partial nitritation, where the ammoniacal nitrogen is partially converted to nitrite, thus providing the stoichiometric conditions required by anammox process.

According to the literature, the nitrogen loading rate (NLR) usually employed vary from 0.06 kg m^{-3} d^{-1} (Xu *et al.*, 2018) to 0.7 kg m^{-3} d^{-1} (Pichel *et al.*, 2018) on the deammonification process for digestate treatment. Considering the relatively high concentration of ammoniacal nitrogen in digestate, the objective of this work was to evaluate the effect of higher NLR, compared to those usually reported in literature.

MATERIAL AND METHODS

The study was carried out at the Laboratory of Experimentation and Environmental Analysis (LEEA) of Embrapa Suínos e Aves - Concórdia/SC. The deammonification process was established in an EGSB, single-stage (working volume of 1 L). Feeding was carried out with a digestate from a continuous stirred tank reactor (CSTR), which operates with high solids concentration (20 %, v v^{-1}) under mesophilic conditions treating swine manure. The main parameters evaluated were: pH, dissolved oxygen (DO), temperature, NH_4^+-N, NO_2^--N, NO_3^--N and total organic carbon (TOC) (Rice *et al.*, 2017). The reactor was monitored for 178 days and was divided into six phases according to the NLR applied during this period that ranged from 1.2 to 3.2 kg m^{-3} d^{-1} (Table 01).

RESULTS AND DISCUSSION

The work involved the reactor monitoring to evaluate how much the increase of NLR affects the efficiency of nitrogen removal. The system started (phase 1) to be fed with digestate at a NLR of 1.22 ± 0.06 kg m^{-3} d^{-1} and the average efficiency of total nitrogen removal (TNR) during this phase was 70 ± 0.07% (Figure

01). It was higher than observed by Pichel *et al.* (2018), that reached a NLR of 0.3 kg m^{-3} d^{-1}. In phase 2, NLR was increased to 1.67 ± 0.21 kg m^{-3} d^{-1} and the TNR efficiency was 66 ± 11 %. In the beginning of this phase the efficiency decreased, but from the 52 operational day the TNR efficiency increased to 66 ± 5.15 % and remained stable until the end of the phase. From 3^{rd} until 5^{th} phase the behavior of TNR efficiency was similar as can be seen at Figure 01, remaining around 78 ± 7.4%. In the phase 6, when the NLR was 3.15 ± 0.02 Kg m^{-3} d^{-1} the TNR efficiency raised to 81 ± 5.9%.

In order to prove the presence of ammonia oxidizing bacteria (anammox), the stoichiometric coefficients for chemical species involved in anammox process were calculated. These values are shown in Figure 02 in comparison to the theoretical coefficients (Buha *et al.*, 2015). The N_2 coefficient remained very close to the theoretical value, which corroborates with the assumption that deammonification process is responsible for the ammonia removal.

Additionally, it was observed that the NO_3^--N coefficient remained below the value established by literature and, therefore, it is assumed that another process occurred along with the deammonification, as for example denitrification. However, the nitrogen removal through denitrification probably was almost negligible because the consumption of TOC during treatment was of about 17 ± 11.5%. As known, organic carbon is the electron acceptor during heterotrophic denitrification. It is important to highlight that the ammonia load used in this work is about 9.3 times higher than normally applied in this type of process (CAO *et al.*, 2017), which shows the robustness of the reactor used in this work.

CONCLUSIONS

The deammonification process is a promising technology in the wastewater treatment with high concentrations of ammoniacal nitrogen as digestate, mainly because the anammox process has a relatively low operational cost in relation to other nitrogen removal processes usually used.

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Table 1. Distribution in phases of experimental days according to the nitrogen loading rate (NLR).

Phase	Operational days	NLR (kg m^{-3} d^{-1})
1	1 – 32	1.22 ± 0.06
2	33 – 74	1.67 ± 0.21
3	75 – 103	2.01 ± 0.04
4	104 – 132	2.44 ± 0.09
5	133 – 170	2.88 ± 0.08
6	171 - 178	3.15 ± 0.02

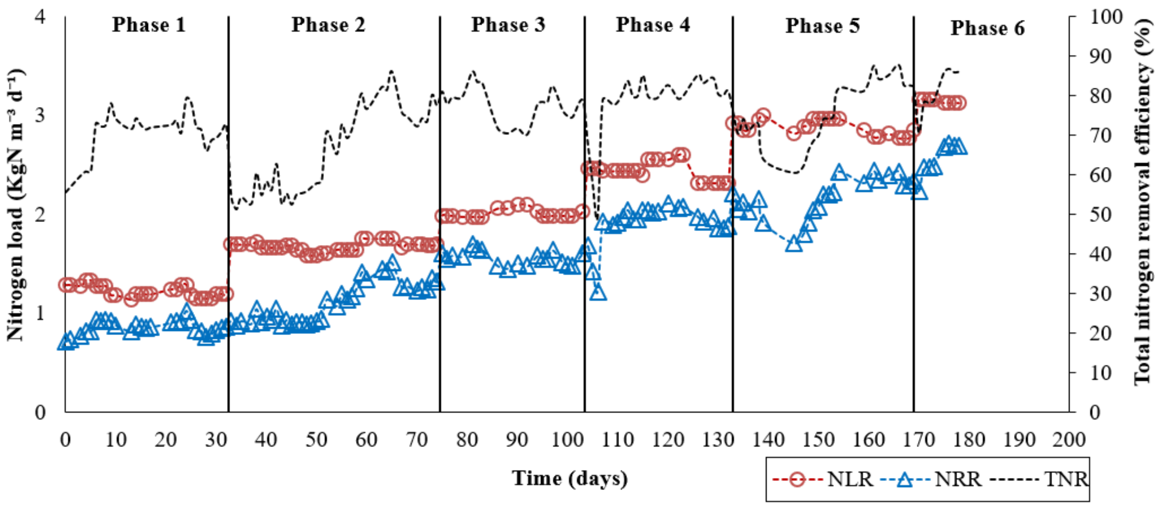

Figure 1. Nitrogen loading rate (NLR), nitrogen removal rate (NRR) and total nitrogen removal (TNR) efficiency of EGSB reactor during the experimental phases.

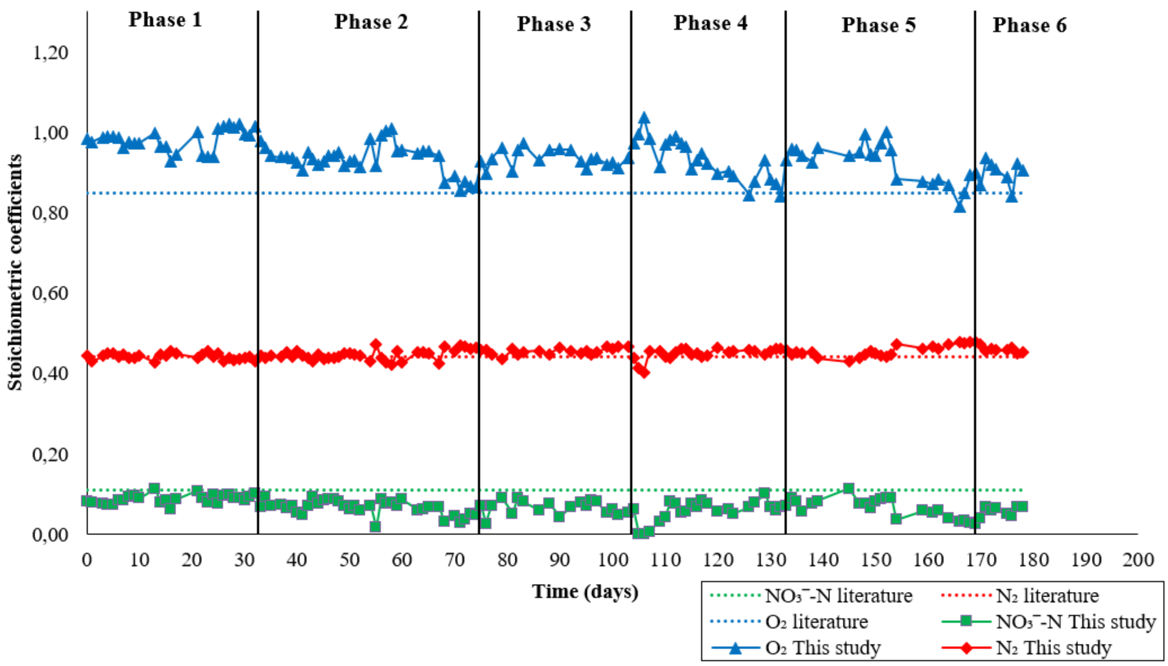

Figure 2. Stoichiometric coefficients calculated from results obtained at this work and at the literature.