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Filtro Anaeróbio de Fluxo Ascendente para Tratamento de Efluente de uma Fábrica que Produz Ração Animal

Upflow Anaerobic Filter for Pet Food Wastewater Treatment

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Resumo

A digestão anaeróbia é um processo largamente utilizado no tratamento de efluentes agroindustriais, onde a maior parte da matéria orgânica está presente na forma dissolvida, além de ser facilmente biodegradável. Neste trabalho foi utilizado um filtro biológico anaeróbio de fluxo ascendente para tratar efluente de uma empresa que processa subprodutos de um frigorífico para produzir ração animal. A Demanda Química de Oxigênio (DQO) do substrato apresentou valores que variaram de 738 a 1102 mg O_2 L^{-1} e teor de Nitrogênio Total Kjeldahl (NTK) de 143 a 723 mg L^{-1}. O filtro foi operado continuamente a temperatura ambiente, com cargas orgânicas que variaram de 0,077 a 1,083 kg COD m^{-3} d^{-1} e Tempo de Detenção Hidráulica (TDH) de 240, 168, 120, 72, 48, 24 e 21 horas. Os melhores resultados de remoção de DQO foram obtidos com TDH de 24 horas, onde o efluente apresentou DQO de 154 mg O_2 L^{-1}. Pode ser concluído que, nas condições empregadas, o processo de digestão anaeróbia é viável.

Palavras-chave: Digestão anaeróbia. Abatedouro. Processos biológicos.

Abstract

Anaerobic biodigestion is a process that has been widely used to agroindustrial effluents treatment, where most of the organic matter is present in dissolved form and is easily biodegradable. In this work we used an upflow anaerobic biological filter to treat effluent from a company that processes byproducts from the meat industry to produce pet food. The substrate had Chemical Oxygen Demand (COD) values ranging from 738 to 1102 mg O_2 L^{-1} and Total Kjeldahl Nitrogen (TKN) contents from 143 to 723 mg L^{-1}. The filter was operated continually at room temperature, with organic loads from 0.077 to 1.083 kg COD m^{-3} d^{-1} and Hidraulic Retention Times (HRT) of 240, 168, 120, 72, 48, 24, and 21 hours. The best COD removal results were obtained under a 24-hour HRT, in which a COD of 154 mg O_2 L^{-1} was obtained for the effluent. It can be concluded that, under the conditions employed, the anaerobic digestion process was effective for COD removal.

Keywords: Anaerobic digestion. Slaughterhouse. Biologic processes.

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Introdução

The pet food industries are an important degree in the cleaner production because they utilize as raw materials the slaughterhouse residues as blood, feathers, lungs and discarded animals. So they transform these byproducts into edible products. Today, with increased concerns about health and the environment, several researches have been conducted to allow a more effective processing and a better use of those byproducts (THOMPSON, 2008). Several types of residues, including slaughterhouse residues, can be degraded anaerobically in order to achieve one of the following: removal of polluting organic load and pathogenic microorganisms, production of biogas and more stable biofertilizers, richer in assimilable nutrients, and with better hygienic conditions in relation to the original material (VALLADÃO et al., 2011; DEL NERY et al., 2007).

Due to an increasing number of regulations regarding the treatment and disposal of residues, as a result of global warming effects caused by the release of gases that intensify the greenhouse effect, the anaerobic digestion of organic residues is an important option to reduce water and soil pollution, as well as gases that cause the greenhouse effect (BUENDÍA et al., 2009). When compared with conventional aerobic systems, anaerobic systems have lower capital and operational costs, require less energy, and generate smaller amounts of sludge, constituting a technology frequently used for wastewater treatment (CHAN et al., 2009). A biological filter is a structure that contains a filling of inert materials such as rocks, plastic, or bamboo sticks, which provide a bed for the growth and adhesion of the biomass responsible for organic matter decomposition, producing treated effluent (BODKHE, 2008). Biofilm processes have been considered as good alternatives due to excellent biomass retention and accumulation in the system (HO; SUNG, 2010). There have been several studies on the treatment of slaughterhouse effluents by anaerobic biological processes (MASSE; MASSE, 2000; CHÁVEZ et al., 2005); however, the effectiveness of biological filters for the treatment of effluents from companies that process meat industry byproducts has not been evaluated. In this work, we evaluated an upflow anaerobic biological filter to treating effluents generated by a company that processes animal feed flavor additives, using byproducts from the slaughter and processing of swine, broiler chickens, and turkeys as raw materials.

Materials and Methods

Wastewater characterization

The wastewater was collected in a company that processes residues generated during swine, broiler chickens and turkeys slaughter to produce pet food flavors. The company generates 240 m^3 of effluent per day, with approximately 18.000 mgO_2 L^{-1} COD and 5.000 mg L^{-1} of oils and greases. The substrate was collected after the DAF (Dissolved Air Flotation) system to remove oils and greases.

After collection, the substrate was stored in 5L capacity polypropylene jars maintained in a freezer at -18°C. The jars were thawed as needed and the volume to be fed into the reactor was heated to room temperature.

The characterization of batches used (five batches) showed variations in the results of parameters analyzed due to the various types of raw materials used for feed flavor additive processing (Table 1).

Tabela 1 – Characterization of substrate batches used in the experiment.

Parameters	Batch1	Batch 2	Batch 3	Batch 4	Batch 5
pH	5.9	6.8	8.8	9.8	9.2
Alkalinity (mg $CaCO_3$ L^{-1})	660	734	573	1218	655
Volatile Acidity (mg CH_3COOH L^{-1})	1693	654	470	604	356
Total Solids (%)	0.22	0.17	0.01	0.16	0.01
Volatile Solids (%)	0.16	0.15	0.01	0.09	0.02
COD (mgO_2 L^{-1})	752	1072	738	1005	1102
Total Kjeldahl Nitrogen (mg L^{-1})	722	556	143	264	200
Ammonia Nitrogen (mg L^{-1})	n.e	n.e	n.e	240	171
Phosphorus (mg L^{-1})	23.6	25.9	5.1	19.6	5.3
Oils and Greases (mg L^{-1})	0.27	3.63	2.28	6.03	2.28

n.e.: not evaluated

Source: The Authors.

Reactor design and operational condition

An upflow anaerobic biological filter was used, built with a PVC (Polyvinyl Chloride) tube measuring 11 cm in diameter and 31.5 cm in height and a usable volume of 980 mL. The biomass support consisted of polypropylene rings with 1cm of diameter by 1cm in length. The biogas left the system through a 1.2 mm diameter hose. The reactor was maintained at room temperature and the inoculum came from a brewery's UASB methanogenic reactor.

The reactor was continually fed through the bottom opening with a peristaltic pump connected to a timer and samples were collected from the top part.

The experiment started with a hydraulic retention time (HRT) of 240 hours. The reactor was initially fed with effluent at an organic load of 0.077 kg COD m^{-3} d^{-1}, until completely filling the usable volume of the reactor (by the end of the 240 hours). This HRT was adopted during the start process to allow the sludge to adapt to the new conditions in use.

After starts the process the filter's HRT was gradually reduced. HRT changes were performed when COD removal reached a steady state. Table 2 shows HRT values used in the reactor, as well as work periods, organic loads, and corresponding batches.

Technical analysis

Table 2 - HRT duration periods and corresponding batches of substrates used in the experiment.

HRT (hours)	Duration (days)	Organic Load (kg COD $m^{-3}d^{-1}$)	Batch of Substrate
240	40	0.077	01
168	15	0.102	01
120	10	0.154	01
72	15	0.356	02
48	27	0.536	02
24	30	0.854	02 and 03
21	59	1.083	03, 04, and 05

Source: The Authors.

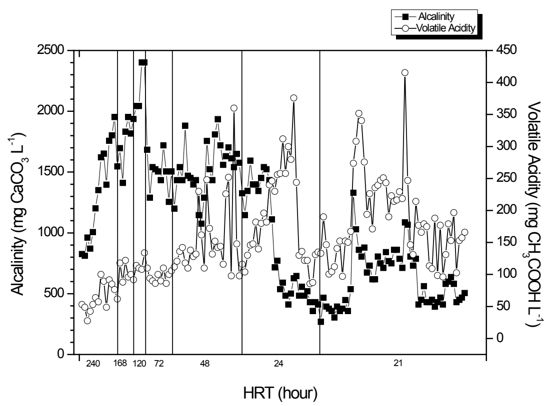
Chemical Oxygen Demand (COD), Oils and Greases (OG), pH, Total Alcalinity (ALK), Volatile Acidity (VA), Total Kjeldahl Nitrogen (TNK) and NH_3-N were determined using standard methods (APHA, 1998). Phosphorus (P) concentration was determined according to the method described in Silva (1981).

Results and Discussion

The pH values for the reactor's effluent remained above 7.0 almost during the entire period analyzed (Table 3), indicating that the system was stable. The highest pH values occurred during the 24-hour HRT, indicating higher consumption of organic acids, probably due to a higher concentration of methanogenic archaea, which convert acids into methane and carbon dioxide. The room temperature during that period showed the highest values, above 25°C.

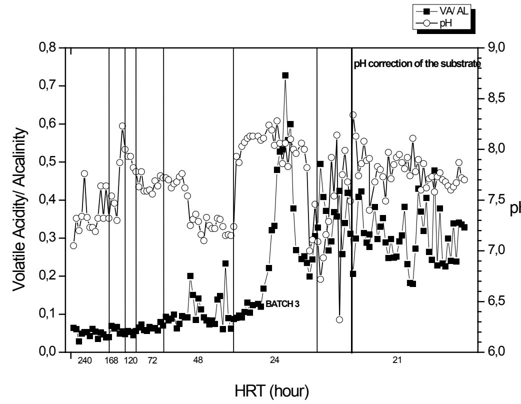
Acidity on the effluent from the biological filter increased as HRT decreased (Fig. 1), but decreased again by the end of the 21-hour HRT, and remained below 250 mg $CH_3COOH.L^{-1}$ during almost the entire experiment; this value is considered ideal to maintain stability during the methanogenic stage (TABATABAEI et al., 2010). The increased VA/ALK ratio may have occurred due to the increased organic load and the use of substrate containing agents that slightly inhibited methanogenic archaea, causing organic acids accumulation in the system. The inhibit factor could be related to the use of alkaline agents to clean the plant floor. Another batch of substrate was used during the 21-hour HRT; pH correction was started by adding HCl 6N to adjust the pH to values between 6.6 and 7.4, which is optimal for methanogenic archaea development. After that procedure, it was observed that the VA/ALK ratio went back to normal and remained below 0.4 (Fig. 2).

Fig. 1. Alkalinity and Volatile Acidity values on the effluent under different HRT.



Source: The Authors.

Fig. 2. Volatile Acidity/Alkalinity (VA/AL) ratio and pH on the effluent under different HRT values

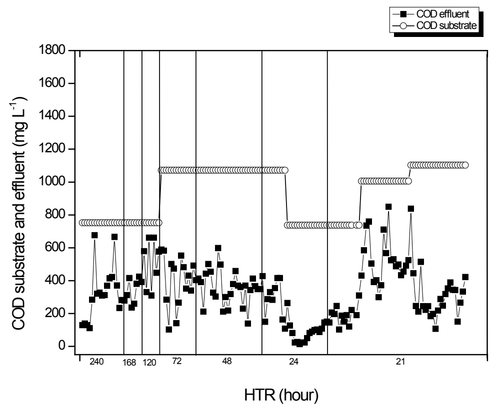


Source: The Authors.

COD Removal

The highest removal of COD occurred during the 24-hour HRT, with a mean value of 83% and an organic load of 0.854 kg COD m^{-3} d^{-1}, corresponding to a COD concentration of 154 mg L^{-1} in the effluent (Fig. 4).

Fig. 3. COD concentration in the substrate and the effluent under different HRTs studied.

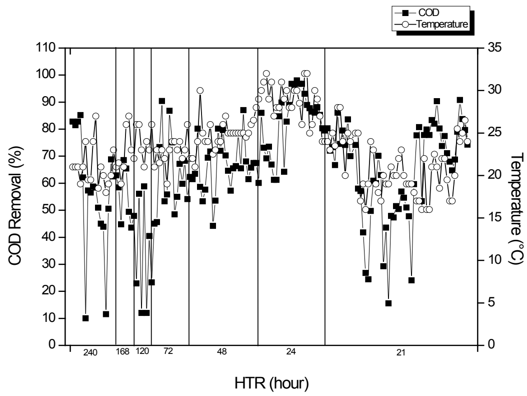


Source: The Authors.

The highest COD removal indices were obtained under HRTs smaller than 72 hours (Fig. 4). This behavior may occur because organic matter removal in biological treatment systems follow a first-order reaction, where the higher the concentration of organic matter in the substrate the higher its removal.

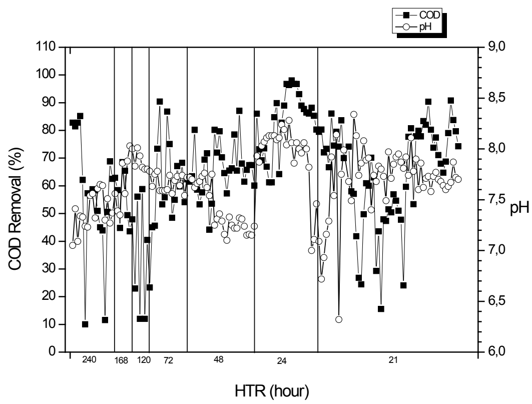
It can also be observed that the period when pH showed the highest values corresponded to the period of highest COD removal (24-H HRT), indicating higher consumption of organic acids and higher activity of methanogenic archaea, which convert organic acids into gases (Fig. 5).

Fig. 4. Temperature inside the reactor and COD removal under different HRTs



Source: The Authors.

Fig. 5. pH Value and COD Removal from the effluent under different HRTs



Source: The Authors.

Total Kjeldahl Nitrogen (TKN) and Phosphorus (P) removal

The TKN removal values for the effluent varied between 3.33 and 26.65% (Table 3). Del Nery et al. (2007) used a primary flotation treatment with dissolved air from a slaughterhouse effluent followed by the use of an upflow anaerobic sludge blanket treatment and could not remove any nitrogen. In anaerobic treatment the TKN is not removed because it is necessary the occurrence of nitrification, an aerobic reaction, and then the denitrification. Santos and Oliveira (2011) do not observed the TKN reduction in the anaerobic treatment of swine wastewater, but only when an aerobic treatment was used combined with.

Wosiacki et al. (2015), working with the same effluent, evaluated the performance of a continuous flow structured-bed reactor with intermittent aeration, and obtained a treated effluent with 30 mg.L^{-1} of NKT, which represented 88% of efficiency.

Table 3 - Average values of TKN, TKN removal, Phosphorous and Phosphorous removal on treated effluent in different HRTs

HRT (hours)	TKN (mg L^{-1})	TKN removal (%)	P (mg L^{-1})	P removal (%)
240	530 ± 231	26.65 ± 32.05	18.99 ± 9.01	19.52 ± 38.17
168	698 ± 56	3.33 ± 7.78	23.80 ± 1.10	0.00 ± 4.68
120	657 ± 8	9.04 ± 1.24	13.96 ± 10.36	40.83 ± 43.90
72	449 ± 15	20.58 ± 2.74	18.48 ± 3.15	28.72 ± 12.15
48	450 ± 38	20.46 ± 6.81	21.59 ± 6.21	16.72 ± 23.96
24	253 ± 166	17.24 ± 12.08	7.48 ± 6.66	49.23 ± 24.22
21	165 ± 35	21.12 ± 9.71	1.85 ± 2.13	65.65 ± 39.60

Source: The Authors.

The ammonia-nitrogen concentrations in the effluent were determined under a 21-hour HRT and had average value of 127.78 mg L^{-1}. Ammonia concentrations between 50 and 200 mg L^{-1} are beneficial to the process. Values in the range from 200 to 1000 mg L^{-1} do not have an adverse effect; an inhibitory effect occurs between 1500 and 3000 mg L^{-1} if the pH is higher than 7.4; when the ammonia concentration is higher than 3000 mg L^{-1} the effects can be considered toxic. Therefore, the ammonia-nitrogen concentrations in the effluent under a 21-hour HRT were considered beneficial to the process.

Kurian et al. (2005) treated effluent from animal feed production in a membrane bioreactor in association with conventional treatment (20°C) and thermophilic treatment (45°C), by initially applying a flotation pretreatment with dissolved air. They observed ammonia-nitrogen removal percentages of 69 and 51% for the thermophilic treatment, under HRT of 7 and 5 days, respectively, corresponding to ammonia-nitrogen concentrations of 197 and 363 mg L^{-1}, respectively. In the conventional treatment, ammonia-nitrogen removal percentages of 59 and 62% were obtained under HRT of 6.3 and 5 days, respectively, corresponding to ammonia-nitrogen concentrations of 487 and 451 mg L^{-1}, respectively.

Acharya et al. (2006) also treated effluent from animal feed in a membrane bioreactor and adopted pre denitrification under HRTs of 12.5 and 6.3 days and obtained ammonia-nitrogen removal percentages of 90 and 99%, respectively.

The phosphorus removal values from the effluent varied between 0.00 and 65.65% (Table 3). Del Nery et al. (2007) applied a primary flotation treatment with dissolved air from a slaughterhouse effluent followed by the application of an upflow anaerobic sludge blanket treatment and could not remove any phosphorus.

CONCLUSION

It can be concluded that an upflow anaerobic filter is effective to COD remove. The 24-hour HRT showed the best results in COD removal rates, 84%, that generated a treated effluent with 154 mg.L^{-1}. The HRT and batch variables utilized had great influence on the results obtained, indicating the importance of using an equalization tank before the biological treatment.

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