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DRIPPERS PERFORMANCE APPLYING TREATED SWINE EFFLUENT

Gustavo H. S. Vieira. Full Professor. PhD.
IFES *campus* Santa Teresa, Rod. ES 080, km 93, São João de Petrópolis, Santa Teresa-ES, Brazil. 29.660-000. e-mail: ghsvieira@gmail.com

Carlos M. M. Poloni. Agronomy undergraduate student.

IFES *campus* Santa Teresa – Rod. ES 080, km 93, São João de Petrópolis, Santa Teresa-ES, Brazil. 29.660-000.

André D. B. Garcia. Agronomy undergraduate student.
IFES *campus* Santa Teresa – Rod. ES 080, km 93, São João de Petrópolis, Santa Teresa-ES, Brazil. 29.660-000.

Paola A. V. Lo Monaco. Full Professor, PhD.

IFES *campus* Santa Teresa – Rod. ES 080, km 93, São João de Petrópolis, Santa Teresa-ES, Brazil. 29.660-000.

Ismail R. Haddade. Professor, PhD.

IFES *campus* Santa Teresa – Rod. ES 080, km 93, São João de Petrópolis, Santa Teresa-ES, Brazil. 29.660-000.

Eduardo F. Oza. Agronomy undergraduate student.
IFES *campus* Santa Teresa – Rod. ES 080, km 93, São João de Petrópolis, Santa Teresa-ES, Brazil. 29.660-000.

Millena M. dos Santos. Agronomy undergraduate student.
IFES *campus* Santa Teresa – Rod. ES 080, km 93, São João de Petrópolis, Santa Teresa-ES, Brazil. 29.660-000.

Abstract: *This study aimed to evaluate the performance of drippers used in fertigation by applying swine wastewater after treatment in anaerobic bamboo filters at the Federal Institute of Espírito Santo, Santa Teresa Campus, Brazil. The effluent from the institution 's swine sector was stored in fiberglass reservoirs with a capacity of 100 L and conducted by gravity for anaerobic bamboo filters with a capacity of 5.8 L each one. After filtration, the effluent was distributed to the drip hoses supported on a workbench, using two different types of drippers (G1 and G2). We evaluated the Distribution Uniformity Coefficient (DU), the Flow Rate Variation Coefficient (Qvc) and the Relative Flow Rate of the emitters (Qr), which did not show changes, even after 300 h of use. Thus, we conclude that swine wastewater treated by anaerobic* *bamboo filters, can be conducted in drip irrigation systems, using both the self-compensating and the non-compensating models, without compromising the distribution uniformity.*

Keywords: uniformity, wastewater, drip irrigation, clogging.

INTRODUCTION

The pork production is one of the most important agricultural activities in the Brazilian territory. According to data from the Brazilian Association of Animal Proteins (ABPA), Brazil, in 2016, ranked as the fourth largest producer of pork in the world, with a production of 3,731 thousand tons, behind China, the European Union and the United States (ABPA, 2017).

Due to the great importance of this activity, aspects such as swine management, production chain management and manure management must always be observed, otherwise they can cause enormous damage to producers, consumers of the product and the environment.

Among the aspects to be observed is the management of manure, since the average production of liquid pig manure is 14 L day^{-1} per animal (Konzen, 2006). Considering that some 21 million animals were slaughtered in the first half of 2017 (IBGE, 2017), there was at least a daily production of approximately 294 million liters of swine wastewater (SWW).

When improperly disposed of, pork wastewater can cause many environmental problems, ranging from soil leaching and contamination, to the pollution of water resources. Faced with this problem, several studies are being developed with the purpose of reducing the impacts caused by this activity.

Among the studies and alternatives, the utilization of swine wastewater (SWW) as an organic fertilizer for several crops is worth mentioning (Antonelli et al., 2014; Costa et al., 2017; Lo Monaco et al., 2017; Menezes et al., 2017). However, in spite of the several papers indicating the use of SWW, few are those that relate their treatment for use in fertigation, with drip application, as well as its effects on these equipments.

Due to the risk of drippers clogging when using wastewater, it is necessary to perform a treatment before these waters are conducted in localized irrigation systems.

Among the simple solutions, proposals for the treatment of wastewater rich in organic material, as is the case of those coming from smaller swine farms, we highlight the anaerobic filter of upward flow. According to Tonetti et al. (2011) anaerobic filters are a low-cost option in both the construction and operational aspects, removing approximately 70% of the organic matter and producing a small amount of sludge.

One of the impediments to the adoption of real-scale anaerobic filters refers to the cost of the filler as the carrier medium, usually the gravel, which may cost the same value as the filter construction (Tonettti et al., 2011). In this sense, alternative materials to the gravel become essential, especially if they are low cost, accessible and allow high efficiency in the treatment of wastewater. Due to the high availability of bamboo in the Centro Serrana region of Espírito Santo state, Brazil, this study aimed to evaluate the performance of different models of drippers by applying swine wastewater treated in anaerobic filters containing bamboo rings as support material.

MATERIAL AND METHODS

The study was carried out at the Instituto Federal do Espírito Santo, Campus Santa Teresa, Espírito Santo state, Brazil (19º 48 'S, 40º 40' W), at 130 meters of altitude above sea level. The climate of the region, according to the classification of Köppen, is classified as Aw, characterizing as megathermic (tropical humid), with dry winter and maximum rains in the summer.

The SWW used in the experiment came from the medium-sized animal sector of the campus. The effluent was stored in a 500 L capacity asbestos tank, installed in a structure 1 m above the filters, causing them to be fed by gravity, as shown in Figure 1A.

The equipment used for effluent treatment consisted of four upflow anaerobic filters units, constructed with 100 mm diameter PVC pipe segments, with a capacity of 5.8 L each, as can be seen in Figure 1B. As filter material we used circular segments of bamboo with average dimensions of 2 cm in height and 3 cm in diameter.

Figure 1. Effluent storage, distribution and filtration structure (A) and top view of the filter showing the filter material (B).

The time of arrest or permanence of SWW in the filters was in accordance with the recommendation of NBR 7229 (1993), which suggests a period of at least 12 hours to complete its treatment completely, without compromising the effluent quality.

For the wastewater characterization, before and after filtration, the following characteristics were analyzed: total solids (TS) and suspended solids (SS) by gravimetric method, turbidity (T) by nephelometric method, total nitrogen (N_T) and total phosphorus (P_T) by the semi micro process Kjeldahl, biochemical oxygen demand (BOD) by the Winkler process and electrical conductivity (EC) by means of digital conductivity meter. All analyzes were carried out at the Laboratory of Water Quality and Solid Waste at the Santa Teresa campus, following the methods described by Matos (2015).

The effluent was submitted to the analysis to evaluate the pollutant removal efficiency of the bamboo filter. To calculate the removal efficiency, Equation 1 was used, from the concentration of the affluent and the effluent at the time of samples collection.

$$\mathrm{Ef} = \frac{\left(\mathrm{C_{af}} - \mathrm{C_{ef}}\right)}{\mathrm{C_{af}}} 100 \qquad (1)$$

Where:

E_f: removal efficiency, %;

C_{af}: affluent concentration;

C_{ef}: effluent concentration.

After the treatment, the effluent was conducted to a tests bench, in which there were two different models of drippers installed for evaluation, which can be observed in Figure 2.

Figure 2. Tests bench for application of treatments and emitters evaluation.

The test bench was assembled using four segments of dripping tubes with 25 units per segment. Each set of two tubes was composed of a dripper model, totaling 50 evaluated drippers of each type, being: (G1) D5000 Flow Regulated self-compensating Drip Line with nominal flow of 2.1 L h-1 and (G2) Naandanjain no and rated flow rate of 1,6 L h-1.The tests bench was assembled using four segments of dripping tubes with 25 units per segment. Each set of two tubes was composed of a dripper model, totaling 50 evaluated drippers of each type, being: (G1) D5000 Flow Regulated self-compensating Drip Line with nominal flow rate of 2.1 L h^{-1} and (G2) Naandanjain non-compensating with a nominal flow rate of 1,6 L h^{-1}.

The bench structure consisted of a system pressurized by a motor pump of 0.5 hp, a plastic tank of 500 L and a disc filtering system of 120 mesh. The system was in accordance with the manufacturer's specifications and pressure gauges were installed at all the dripping tubes, guaranteeing the pressure system uniformity.

Cada agrupamento de gotejadores passou por avaliações em função do tempo de uso, sendo 0; 48; 120; 200 e 300 horas, aplicando o efluente do filtro anaeróbio de forma contínua, completando-se o nível do reservatório a cada avaliação. Foram avaliados o coeficiente de uniformidade distribuição (CUD), o coeficiente variação de vazão (CVQ) e a vazão relativa dos emissores (Qr), conforme as equações 2, 3 e 4, respectivamente.

Each group of drippers was evaluated according to the time of use, being 0; 48; 120; 200 and 300 hours, applying the effluent of the anaerobic filter continuously, completing the level of the reservoir with each evaluation. The emission uniformity (DU), the flow rate variation coefficient (FVC) and the relative flow rate of the emitters (Qr) were evaluated, according to equations 2, 3 and 4, respectively.

$$EU = \frac{q_{25\%}}{\bar{q}}\ 100 \quad (2)$$

Where:

EU = emission uniformity, %;

$q_{25\%}$ = average discharge rate of the lowest one-fourth data emitter readings, L h^{-1};

$\bar{q}$ = average discharge rate of all the emitters checked, L h^{-1}.

$$FVC = \frac{S}{q_m}\ 100 \quad (3)$$

Where:

FVC = flow rate variation coefficient, %;

S = standard deviation os samples, L h^{-1};

q_m = average of measured flow rates, L h^{-1}.

$$Q_r = \frac{Qa}{Qi}\ 100 \quad (4)$$

Where:

Qr = relative flow rate, %;

Qa = real flow rate, L h^{-1};

Qi = initial flow rate, L h^{-1}.

The interpretation of the emission uniformity (EU) values was based on the methodology proposed by Merriam and Keller (1978), presented in Table 1.

Table 1. Classification of performance values of the emission uniformity.

Evaluated parameters	**Classification**
90% a 100%	Excellent
80% a 90%	Good
70% a 80%	Regular
Lower than 70%	Bad

Adapted from Merriam and Keller (1978).

RESULTS AND DISCUSSION

The physical-chemical attributes of the effluent obtained in the swine wastewater, before and after treatment with bamboo filters, as well as the removal efficiency can be observed in Table 2.

Table 2. Affluent concentration (Caf), removal efficiency (%) and effluent concentration (Cef) values for total solids (TS), suspended solids (SS), turbidity (Tb), total phosphorus (Pt), total nitrogen (Nt), biochemical oxygen demand (BOD), electrical conductivity (EC) and pH

Parameter	Caf	Removal efficiency (%)	Cef
TS (mg L^{-1})	2,931.32	51.08	1,434.00
SS (mg L^{-1})	1,115.17	88.75	125.46
Tb (NTU)	299.6	79.40	61.72
Pt (mg L^{-1})	44.21	70.57	13.01
Nt (mg L^{-1})	6,724.00	24.33	5,088.05
BOD (mg L^{-1})	282.16	23.42	216.08
EC (dS m^{-1})	4.31	15.62	3.64
pH	8.24	-	7.20

We can see that, after the filtration of SWW, there was a significant reduction in the observed parameters, mainly in relation to suspended solids and water turbidity.

According to Ayers and Westcot (1985), water with concentrations greater than 100 mg L^{-1} of SS and 2,000 mg L^{-1} of TS, the chance of drippers clogging becomes severe. After the filtration, the quality of water used for irrigation was classified as a severe risk of clogging for SS (125.46 mg L^{-1}) and moderate risk for TS (1,434.00 mg L-1), because it is within the range between 450 and 2,000 mg L^{-1}.

Although classified as a severe risk, SS concentration was slightly above that recommended by Ayers and Westcot (1985), indicating that the treatments with the bamboo filters showed good results in the removal efficiency of the evaluated parameters.

According to Almeida (2010), care must be taken when using irrigation water with suspended particles, which can cause drip obstructions due to small holes (0.75-1.40 mm) and special geometric shapes (spiral, labyrinth, etc.) through which the water flows.

Figure 3 shows the emission uniformity (EU) in the drippers models self-compensating (G1) and non-compensating (G2), as a function of the time of application of wastewater treated with anaerobic filter, having bamboo rings as support material.

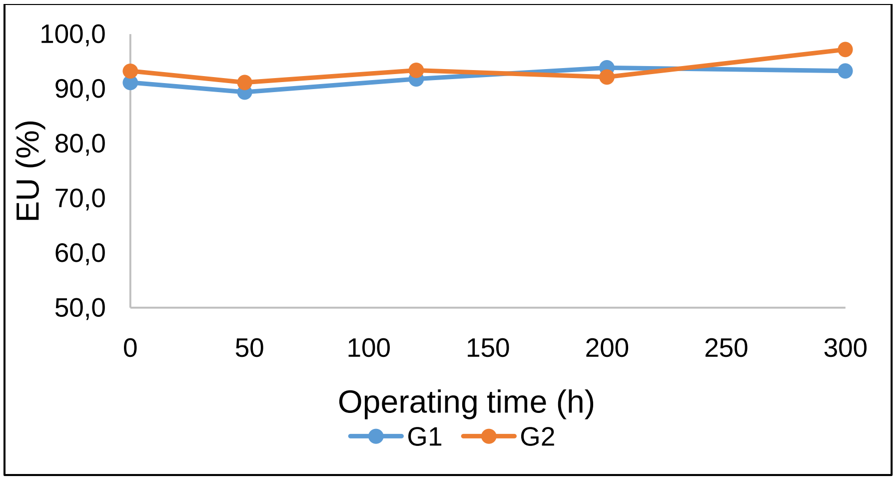

Figure 3. Emission uniformity in the drippers self-compensating (G1) and non-compensating (G2) models, depending on the time of application of wastewater treated with anaerobic filter.

According to the classification proposed by Merriam and Keller (1978) it can be affirmed that the emitters performance is considered excellent throughout the operating time, since the EU average was above 90% for both models. In a study by Batista et al. (2008), the application of swine effluents by drippers, after 160 hours, there was a high reduction in the emission uniformity due to the growth of biofilm internally in the emitters and consequent clogging. The occurrence of biofilms inside the drippers and lateral lines due to the interaction of bacterial mucilages with organic and inorganic particles is the main cause of obstruction in localized irrigation systems that operate with wastewater (Dazhuang et al., 2009; Oliver, et al., 2014).

The maintenance of high levels of emission uniformity was possible due to the low concentrations of particles in the water, indicated by the low turbidity value (61.72 NTU), including, for this parameter, the recommendations of Resolution #430 (BRASIL, 2011), which complements and amends CONAMA Resolution 35,705, which establishes that turbidity of up to 100 NTU for class II waters is suitable for use in irrigation of vegetables, fruit trees and parks, gardens, sports fields and leisure, with which the public can come into direct contact.

Os coeficientes de variação da vazão nos dois tipos de gotejadores em função do tempo de operação são apresentados na Figura 4.

The flow rate variation coefficients for the two types of drippers as a function of the operating time are presented in Figure 4.

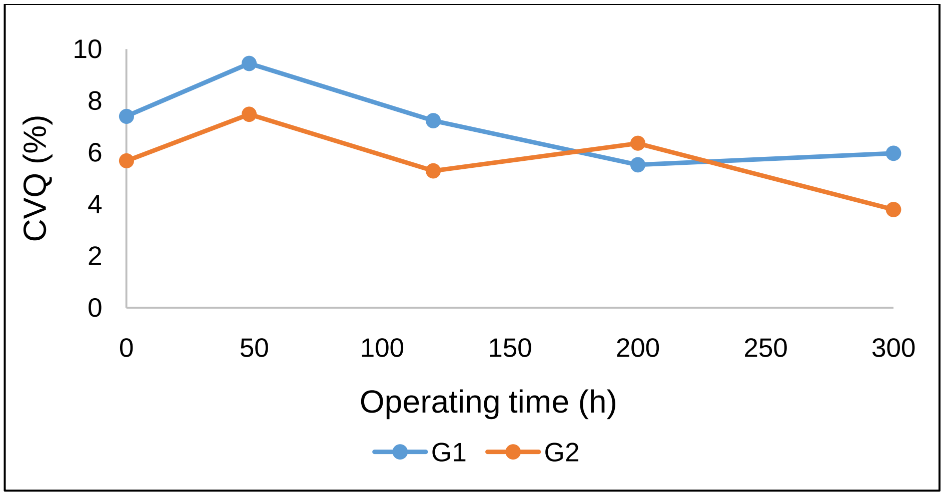

Figure 4. Flow rate variation coefficients for the two types of drippers as a function of the operating time.

In the same way as observed for the EU, there was little flow rate variation during the evaluation period, for both models of drippers, indicating that the SWW treated with anaerobic bamboo filters can be used for fertigation in irrigation systems without compromising the water distribution uniformity.

Table 3 presents the values of flow rate relative to the initial as a function of the operating times of the drippers. It is observed that the relative flow rate remained practically the same throughout the evaluation period, indicating that the dripper models evaluated can be used to apply filter-treated swine wastewater.

Table 3. Relative flor rate of the emitters.

Dripper	Initial flow rate ($L\ h^{-1}$)	Relative flow rate - Qr (%)			
		Operating time (h)			
		48	120	200	300
G1	2.51	94	93	92	91
G2	2,12	104	102	102	104

The results obtained in this study differ from those obtained by Batista et al. (2011) who, when using treated domestic sewage in maturation ponds, observed that there was a reduction in the flow rate of the drippers of the studied irrigation systems, attributing this result to the higher concentration of suspended solids in the evaluated treatments.

CONCLUSIONS

Swine wastewater, treated by anaerobic bamboo filters, can be appplied by drip irrigation systems, using both the self-compensating and the non-compensating models, without compromising the uniformity of distribution.

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