Fertilizer effect of UASB (55^{o}C) effluent with limestone as fixed bed treating vinasse on development of *Brachiaria Brizantha* cv. Xaraés

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Abstract
The vinasse is a residue from the production of sugar and alcohol, which can be used to fertirrigation, however its use untreated can pollute the soil and water. The objective was evaluated a thermophilic (55^{o}C) upflow anaerobic sludge blanket (UASB) treating vinasse using fixed bed with limestone as a buffer agent to avoid rapidly acidifying and the initial effect of applying the irrigation effluent on *Brachiaria Brizantha* cv. Xaraés. The use of treated vinasse provides biogas generation and effluent to the use of irrigation has a lower pollutant load to the soil and water, allowing its use in the development of forage for use as food at livestock production system.

Keywords
Anaerobic digestion; fertirrigation; agro-industrial wastewater; biogas; livestock.

INTRODUCTION

In Brazil the sugar and alcohol comes from the sugarcane. This process results in a great quantities of residues as ashes, bagasse, gas emissions and vinasse (Vaccari et al., 2003). The sugarcane vinasse is a residue of great concern, due to the quantities (for each liter of alcohol produced, 12 - 14 liters of vinasse is generated) and polluter potential, with high organic load that can exceed 100 g.L^{-1} of chemical oxygen demand (Wilkie et al., 2000), pH around 4.5, output temperature approximately 90^{o}C and potential fertilizer (nitrogen, phosphorus, potassium). However its use *in natura* improve agricultural productivity, but there is a potential polluter of soil and water, which can be minimized with proper treatment (Ribas and Cereda, 2003).

The Upflow Anaerobic Sludge Blanket (UASB) process has been succesfully used for different types of wastewater (Lettinga and Hulshoff, 1992). This technology can be used for energy production and reduction of organic matter in the waste (El-mashad et al., 2004). In Brazil, with the energy matrix based on hydropower (Pottmaier et al., 2013), and climate change increasingly evident, it is important to get alternatives to generate energy, and reduce greenhouse gases, with the objective of sustainable development (De Baere, 2000).

However, it is not common to treat vinasse in Brazil. Application in soil as a fertilizer for sugar-cane crops is the most common practice actually. Wich can results in impacts as soil salinization, leaching of metals and sulphate, groundwater contamination, malodours and attraction of insects (Moraes et al. 2015).

Thus, one option is UASB in thermophilic range (Harada et al., 1996), since the vinasse in the process output enters the reactor at a temperature above 60 ^{o}C, which may take the reactor operating in a better performance. In addition the treated effluent can irrigate forage crops that are used as feed in livestock production and avoid the pollution and environmental impacts. There by, the adoption of such technology in biorefineries could potentially leads to profits from energy, environmental, and economic perspectives, thus optimizing the plants in terms of sustainability (Moraes et al. 2015).

In this sense, this work presents a possibility to the integration of agriculture (production of sugar cane) and livestock (production of fodder crops for livestock), in addition to energy generation and reuse of agro-industrial effluent with better quality, preventing pollution of soil and water and adding value to the residue.

The objective was evaluated a initial operation of a thermophilic (55 ^{o}C) UASB treating vinasse using fixed bed with limestone as a buffer agent to avoid rapidly acidifying and the effect of applying the irrigation effluent on *Brachiaria Brizantha* cv. Xaraés.

MATERIALS AND METHODS

Thermophilic (55^{o}C) UASB

The two lab-scale reactors consisted of a PVC cylinder 1 m high and 20cm diameter (Figure 1). The total volume of reactor was 27 L and 50% with limestone (13.5 L; size: 25-19 mm) as fixed bed to maintain a near neutral pH. The reactor was inside of a metallic drum (120 L) with engine oil to be heater at 55 ^{o}C. The biogas produced was collected in a gas holder floating in a solution of 3% H_2SO_4 and 25% NaCl to remove CO_2, which allowed the measurement of methane gas production.

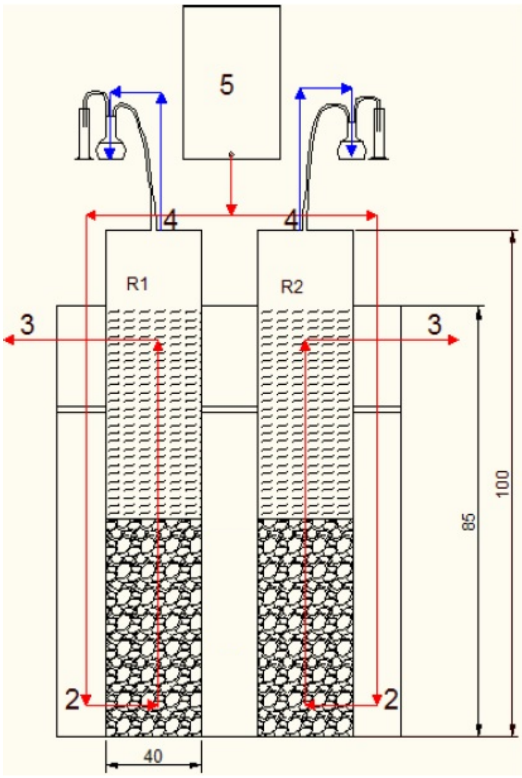

Figure 1. Experimental set-up: (1) heater; (2) inlet; (3) effluent output; (4) biogas output; (5) equalization tank. *Red line:* vinasse; *Blue line:* Biogas. Dimensions in milimeters.

Substrate and anaerobic sludge

Sugarcane vinasse originated from ethanol factory (located 400 km from local study) with initial temperature at 100 ^{o}C and after 6 hour the temperature dropped to 60 ^{o}C and pH 4.3. Vinasse was stored at -20 ^{o}C in 20 liter bottles. The biomass used originated from cattle manure (8 kg), common in rural area, inoculated with water (20.5 L).

Samples and vinasse used in this experiment

Samples of vinasse influents and effluents of the reactor were analyzed three times a week. The samples were analyzed in triplicate and the following parameters: chemical oxygen demand (COD), total solids (TS), volatile solids (VS), fixed solids (FS), alkalinity (Alk.), volatile acidity (VA) and pH. These determinations were carried out according to the Standard Methods for the Examination of Water and Wastewater (APHA, 2012). Vinasse datas used in this experiment are presented in Table 1.

Table 1. Concentration of raw vinasse applied in UASB and concentration of treated vinasse used to *Brachiaria Brizantha* cv. Xaraés growth.

Parameters	Concentration raw vinasse	Concentration treated vinasse
pH	4,3	5,3
COD ($g.L^{-1}$)	16,7	2,0
Total solids ($mg.L^{-1}$)	14.253,0	1.464,0
Total volatile solids ($mg.L^{-1}$)	12.652,3	504,0
Total fixed solids ($mg.L^{-1}$)	1.477,0	960,0
Total phosphorus ($mg.L^{-1}$)	7,0	17,0
Total nitrogen ($mg.L^{-1}$)	3,1	40,0
Calcium ($mg.L^{-1}$)	60,9	47,5
Iron ($mg.L^{-1}$)	4,6	1,86
Potassium ($mg.L^{-1}$)	420,0	223,0
Magnesium ($mg.L^{-1}$)	105,9	51,3
Manganese ($mg.L^{-1}$)	17,4	0,89
Zinc ($mg.L^{-1}$)	3,3	0,09

Initial growth of *Brachiaria Brizantha* cv. Xaraés and statistical analysis

Four treatments were used: control (without fertilizer addition); fertilization; raw vinasse (535 $m^3.ha^{-1}$) and treated vinasse (567 $m^3.ha^{-1}$). Randomized block design with six repetitions. The vinasse was applied fifteen days after sowing and were made two cuts during the experiment (after 40 and 80 days). At the end of the evaluated cycle (80 days) the seedlings were evaluated for height, fresh and dry total mass, fresh and dry leaf mass and fresh and dry stem mass. The multiple mean comparisons within treatments were performed using Tukey's test at a 0.05 error level.

The soil collected in this study presents sandy medium texture (Table 2), according to the criteria of the Brazilian System of Soil Classification (EMBRAPA, 2006).

Table 2. Physico-chemical analysis fo the soil.

	Parameters												
	pH	OM	K	Ca+Mg	Al+H	S	T	V	Fe	Mn	Zn	Cu	B
Units		$g.dm^{-3}$			$cmol.dm^{-3}$			%			$mg.dm^{-3}$		
Values	4,97	6,86	0,03	0,3	2,34	0,33	2,67	12,36	144,96	12,02	0,94	0,9	0,09

RESULTS AND DISCUSSION

Thermophilic UASB operation

Table 3 shows average values of results during the operation of the UASB reactors. It is observed that the lime was effective in alkalinity formation in the medium. Even with the gradual increase in temperature (to obtain the desired temperature - 55 °C) and the organic load applied, the reactors were effective in removing organic matter (COD, solids) and biogas production. With temperatures above 48 °C the reactors showed values above 90% efficiency in COD removal and TVS . These values are higher than the results obtained by (Ribas et al., 2009) conducted a study similar to the treatment of vinasse in thermophilic temperature using NaHCO3 as a source of alkalinity, and observed a maximum removal of organic matter 70%.

Table 3. Start up UASB reactor operation results: removal (%) of COD and solids, pH, alkalinity and volatile acids and biogas production compared to organic load, hydraulic detention time and temperature range.

ºC	**days**	**HDT**	**OL**	**COD (%)**	**TS (%)**	**TVS (%)**	**TFS (%)**	**Alk.**	**VA**	**pH**	**biogas $mL.L^{-1}.d^{-1}$**
36 ± 2	0-29	7	0,5	70,6±3,2	69,0±5,3	78,6±4,7	20,7±6,2	35,0±12,1	242,2±16,1	8,4±0,9	125±15
40 ± 2	30-59	5	1,3	75,1±2.1	81,9±3,7	86,5±2,2	27,6±4,3	50,0±10,3	292,4±14,9	8,1±0,8	165±25
44 ± 2	60-89	5	3,3	77,3±8,5	82,0±9,2	88,1±4,1	34,5±3,7	80,0±9,8	74,4±12,7	7,8±0,5	200±22
48 ± 2	90-104	4	6,7	91,7±1,9	91,7±3,1	91,0±2,9	35,0±4,9	120,0±11,6	60,0±13,4	7,7±1,0	350±35
52 ± 2	105-119	3	8,5	98,2±1,0	84,0±2,9	94,5±1,9	35,5±2.5	150,0±14,7	83,6±7,1	8,7±1,1	500±15
> 55	120-141	3	11,7	99,5±0,9	89,7±1,8	96,0±2,5	35,7±1.7	170,0±15,5	76,8±8,2	8,5±1,4	500±18

ºC: temperature; HDT: hydraulic detention time (days); OL: organic load ($gCOD.m^{-3}.day^{-1}$); TS: total solids (%); TVS: total volatile solids (%); TFS: total fixed solids (%); Alk.: Alkalinity ($mgCaCO_3.L^{-1}$); VA: Volatile Acidity ($mgCH_3COOH$.L-1).

Development cof *Brachiaria Brizantha* cv. Xaraés

The use of raw and treated vinasse did not significantly influence the vegetative development of *Brachiaria brizantha* cv. Xaraés during the first and second crop (Table 4). In the second cut, treated vinasse was significantly higher compared to control (without fertilizer), which indicates the benefit of using for culture in advanced stages.

The low growth relative to treatment with chemical fertilizer can be associated with soil pH to below 4.5. The ideal range for the absorption of most nutrients by plants is around 6.0 (Fageria & Zimmermann, 1998). This lower development of *Brachiaria brizantha* cv. Xaraes a function of pH it can be justified when compared to plants which were not made fertilization of soil, which had pH 4.97.

Table 4. Height measurements and fresh and dry mass, leaf and stem, in the first and second cut.

Treatment fertilizer	Height cm	FTM	LFM	SFM	DTM	LDM	SDM
				gram			
First cut							
Control	42,17 b	2,27 b	2,09 b	0,19 b	0,67 b	0,39 b	0,03 b
Chemical fertilizer	92,17 a	47,80 a	37,42 a	9,93 a	11,47 a	9,43 a	1,97 a
Raw vinasse	36,92 b	2,97 b	2,71 b	0,24 b	0,60 b	0,55 b	0,02 b
Treated vinasse	37,92 b	2,04 b	2,0 b	0,06 b	0,37 b	0,37 b	0,07 b
CV	22,03	34,04	31,69	32,51	20,85	22,42	17,73
Second cut							
Control	69,33 c	42,02 b	26,42 b	15,62 b	8,37 b	5,78 b	2,59 b
Chemical fertilizer	88,83 a	123,18 a	72,97 a	50,80 a	32,84 a	21,06 a	11,79 a
Raw vinasse	69,67 bc	45,53 b	28,20 b	17,30 b	9,36 b	6,42 b	2,94 b
Treated vinasse	78,33 b	41,76 b	25,72 b	16,65 b	8,83 b	5,76 b	3,07 b
CV	6,96	26,15	24,70	27,21	23,50	22,32	23,53

Means followed by the same letter in the column do not differ by Tukey test ($p > 0.05$). FTM = fresh total mass; LFM = leaf fresh mass; SFM = stem fresh mass; DTM = dry total mass; LDM = leaf dry mass; SDM = stem dry mass; CV = coefficient of variation.

Difference between products

As there is no significant difference between the treated vinasse and *in natura* (raw vinasse), this result shows that treatment does not change the nutritional properties of the waste. In addition to this factor, the anaerobic process is also advantageous for potential energy (biogas production).

Vinasse options considering fertirrigation in area with sugarcane

Evaluating the present composition of nutrients in stillage (raw and treated) with the nutritional needs of *Brachiaria brizantha* cv. Xaraés, it is observed that the low concentration of total nitrogen is not presented as a limiting factor, because the grassland established not applicable N for this nutrient to be available the mineralization of organic matter.

When evaluating the application in sugarcane culture (pure or consortium), where the vinasse is already applied as fertilizer, there is a need for complementary fertilization with urea due to nutritional need this culture (van Haandel, 2005). Considering this factor, and the possibility of the biogas power generation. An option would be the addition of urea measurements in the anaerobic treatment together or separately limestone (Boncz et al, 2012; Van Haandel, 2005). Urea is hydrolyzed during the anaerobic digestion, forming NH_3 and CO_2, increasing alkalinity within the reactor. Furthermore the effluent would be suitable for use in soils cultivated with sugarcane.

CONCLUSIONS

- The inoculum (cattle manure) demanded 140 days to stabilize (start-up);
- The reactor had removed 99% for COD in the thermophilic range, showed higher solids removal;
- With increasing temperature (mesophilic - thermophilic) the gas production increased more than 40%;
- The use of raw vinasse did not significantly influence the vegetative development of *Brachiaria brizantha* cv. Xaraés. The treated vinasse benefited the growth after 40 days

after sowing ("second cut");

- The use of treated vinasse at UASB (55°C) provides biogas generation and effluent to the use of irrigation has a lower pollutant load to the soil and water, allowing its use in the development of forage crop for use as food at livestock production system.

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