Dolomitic limestone as an alkalizing agent for treating cassava starch wastewater in an anaerobic reactor[1]

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ABSTRACT

Cassava processing wastewater has a low Volatile Acidity/Total Alkalinity ratio, low buffering capacity and became quickly acidified. In this trial, dolomitic limestone was used as an alkalizing agent in an anaerobic reactor to treat cassava starch wastewater. The dolomitic limestone contained 27% CaO and 23% MgO and granulometry between 24.5 and 38.1 mm. The average Chemical Oxygen Demand of the wastewater was 13331.30 $mgO_2 L^{-1}$, the organic loading rates (OLR) ranged from 1.23 to 16.43 gCOD $L^{-1} d^{-1}$ and the hydraulic retention times ranged from 10.00 to 0.80 days. The results showed that the calcium concentrations increased in the reactor effluent and the magnesium concentrations decreased as the organic loading rates increased. Ca^{2+} and Mg^{2+} concentrations were approximately 5,000 and 5.05 times greater in the sludge than in the inoculum, respectively. The average pH, Total alkalinity, Volatile Acidity and Volatile Acidity/ Total alkalinity values were 6.69, 882.54 $mgCaCO_3 L^{-1}$, 221.55 $mgCH_3COOH L^{-1}$ and 0.22, respectively. The loss of limestone mass corresponded to only 2.51% of the initial mass, after 134 days of anaerobic reactor operation. Finally, it was concluded that the limestone effectively controlled acidification through the alkalinity increased in the system.

Keywords: acidity; alkalinity; calcium; magnesium.

RESUMO

Calcário dolomítico como agente alcalinizante para tratamento de água residuária de fecularia em reator anaeróbio

A água residuária do processamento da mandioca tem baixa relação Acidez Volátil/Alcalinidade Total, baixa capacidade de tamponamento e torna-se rapidamente acidificada. Neste ensaio, calcário dolomítico foi usado como um agente alcalinizante em um reator anaeróbio para tratar a água residuária de fecularia. O calcário dolomítico continha 27% de CaO e 23% MgO e granulometria entre 24,5 e 38,1 mm. A Demanda Química de Oxigênio média do efluente era 13.331,30 $mgO_2 L^{-1}$, as taxas de cargas orgânicas variaram de 1,23 a 16,43 gDQO $L^{-1} d^{-1}$ e o tempo de retenção hidráulica variou de 10,00 a 0,80 dias. Os resultados mostraram que concentração de cálcio aumentou no efluente do reator e as concentrações de magnésio diminuíram com o aumento da carga orgânica. As concentrações de Ca^{2+} e Mg^{2+} eram de aproximadamente 5,000 e 5,05 vezes maiores no lodo do que no inóculo, respectivamente. O pH, alcalinidade total, acidez volátil e acidez volátil/alcalinidade total foram 6,69, 882,54 $mgCaCO_3 L^{-1}$, 221,55 $mgCH_3COOH L^{-1}$ e 0,22, respectivamente. A perda de massa do calcário correspondeu a apenas 2,51% da massa inicial, após 134 dias de operação do reator anaeróbio. Finalmente, concluiu-se que o calcário controlada eficazmente acidificação através do incremento de alcalinidade no sistema.

Palavras-chave: acidez; alcalinidade; cálcio; magnésio.

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INTRODUCTION

In Brazil, starch industries generate 2.6 m^3 of root wash water and 3.6 m^3 of water of starch extraction per ton of processed manioc (Pinto & Cabello, 2011). The physico-chemical characterization of the wastewater of cassava industry may vary depending on the variety of the roots and starch extraction process (Camili & Cabello, 2008). Starch production generates wastewater with organic matter concentrations of up to 15000 mg L^{-1} (Kuczman *et al.*, 2011). The pH of this wastewater varies from approximately 4.0 (Duarte *et al.*, 2012; Sun *et al.*, 2012) to 6.5 (Cassoni & Cereda, 2011).

Cassava processing wastewater requires treatment because it is a pollutant. Anaerobic reactors are able to tolerate high organic loading and offer the possibility of operating with high solids retention times (Aquino & Chernicharo, 2005). In anaerobic treatment, pH stability is one of the most important factors. The optimum pH range for the growth of methanogenic archaea is between 6.6 and 7.6; however, methane (CH_4) formation may occur across the wider pH range of 6.0 to 8.0. In addition, pH values below 6.0 and above 8.3 must be avoided in order to prevent the inhibition of methanogenic Achaea (Chernicharo, 2007).

Dolomitic limestones mainly composed of Ca and Mg oxides were analysed previously by Brazilian researchers to treat wastewater from the cassava flour (Ribas & Cereda, 2004), vinasse (Oliveira Júnior *et al.*, 2012) and cassava starch industries (Palma *et al.*, 2018). The obtained results have indicated that Ca and Mg oxides serve as neutralizing agents and as fixed beds, mainly in rural areas. The authors observed bicarbonate alkalinity directly through the limestone surface wear; thus, $CaCO_3$ availability was increased slowly to avoid sudden changes in pH and eliminate the need of devices for dosing powder and liquid alkalizing agents. Thus, because alkalinity must be maintained during cassava processing wastewater treatment in anaerobic reactors, this paper aims to analyse the efficiency of dolomitic limestone as an alkalizing agent.

MATERIAL AND METHODS

The horizontal tubular reactor used in this study was made of polyvinyl chloride and 90 cm long and had a diameter of 15 cm, a total volume of 15.9 L and a useable volume of 7.95 L. Two floating dome gasometers were connected to the reactor to determine biogas production. The larger diameter tube of the gasometer (20 cm) was capped at its base and filled with H_2O to form a water seal. The smaller diameter tube (15 cm) was capped at its upper end and had a biogas removal valve. The reactor was supplied daily, and cassava proceeding wastewater volume was distributed sequentially by means of a peristaltic pump coupled to a timer (Figure 1).

The wastewater was obtained in a cassava starch industry (Toledo, PR, Brazil). After the samples were selected for characterization, the wastewater was stored at -4 ºC and thawed at room temperature before using it to feed the reactor. The sludge used in the inoculum was collected from a pilot-scale digester used for treating starch wastewater from the same starch industry where wastewater was collected for this experiment. The inoculum consisted of 30% sludge, 10% starch extraction wastewater, and 60% distilled water, which was calculated based on the useable reactor volume. Table 1 shows the averaged inoculum characteristics and the characteristics of the five batches of cassava processing wastewater used in the trial.

Dolomitic limestone was used as the support material and contained 27.33% CaO and 22.97% MgO according to the technical reports of the supplier company. The rocks were standardized according to their granulometry. In this trial, limestone that passed through an ABNT 1½” sieve and was retained on an ABNT 1" sieve (Brazilian Association of Technical Standards) was used. Thus, the limestone was between 24.5 and 38.1 mm in diameter. The rocks were then dried in an oven (60 ºC to 24 h), cooled to room temperature in a desiccator and weighed. The rocks were divided into 6 sets with weights from 1256.71 to 1292.33 g. Each set was placed in a plastic raffia net (Figure 1). The nets were placed along the reactor profile to account for 50% of its useful volume (Ribas & Barana, 2003).

The reactor was operated using mesophilic temperature conditions (27 ºC) that were maintained by a water bath system during the 140-d trial. Cassava processing wastewater COD served as the basis for determining the following organic loading rates: 1.23, 1.54, 1.84, 2.45, 3.40, 4.96, 6.01, 8.11, 10.14, 12.39, 14.79 and 16.43 g COD L^{-1} d^{-1} with respective hydraulic retention times of 10.00, 7.99, 6.65, 5.00, 4.42, 1.69, 1.39, 2.21, 1.77, 1.45, 0.88 and 0.80 days. At the OLR transition from 3.4 to 4.96 gCOD L^{-1} d^{-1} (TDH 4.42 and 1.69 d, respectively), the reactor affluent flow was increased to a value 6 times higher than that used in OLR above. This procedure had as objective to evaluate the performance of the overloaded reactor. However, there was drag of solids from the reactor, with loss of biomass in the effluent during the organic loading rates of 4.96 and 6.01 gCOD L^{-1} d^{-1}. Thus, it was necessary to reduce the flow rate to a value that did not result in biomass loading. This explains the TDH 2.21, 1.17 and 1.45 days, higher than the two immediately preceding.

The organic loading rates was always increased after the reactor stabilized following the previous organic loading rates increase, which was considered to occur when the pH remained unchanged for at least three days, the AV/AT ratio was below 0.5, and constant biogas production occurred.

In each organic loading rate (OLR), after the pH values stability was verified, samples of the reactor effluent were collected during three consecutive days for the chemical analyzes: Ca and Mg concentrations, pH, partial alkalinity (PA), intermediate alkalinity (IA), total alkalinity (TA), volatile acidity (VA), volatile acidity/total alkalinity ratio (VA/TA), volatile fatty acids (VFA) and chemical oxygen demand (COD), according to the methodologies described in Table 1. For volatile organic acid content analysis, the samples were diluted 2.5 times, acidified with 400 µL of a 2 M sulfuric acid solution and analysed using High-Performance Liquid Chromatography as follows: using an Allure Organic Acids column (250 mm x 4.6 mm), a UV detector with a wavelength of 208 nm, a temperature of 47 ºC, a flow rate of 0.6 mL min^{-1} and 90% mobile phase A (formed by water with 0.05% trifluoroacetic acid) and 10% mobile phase B (formed by acetonitrile with 0.025% trifluoroacetic acid). The detection times of lactic acid, acetic acid, propionic acid and butyric acid were 5.7, 6.9, 11.4 and 24.7 min, and the total detection time was 30 min.

At the end of the trial, the top part of the reactor was opened and the liquid above the sludge was removed. The limestone bags were carefully removed and washed with distilled water to remove any adhered sludge. The limestone dry weight lost due to surface corrosion was determined. The bottom sludge samples were collected at three points along the length of the reactor (15, 45 and 75 cm) for determination of calcium and magnesium concentration.

All analyzes were performed in triplicate and the data were analyzed using the statistical software Minitab Version 16.0. The parameters that showed variance homoscedasticity and presented a significant p-value were subjected to Tukey's comparison test at a 5% significance level.

RESULTS

During the test, the calcium concentration in the reactor effluent was higher than the concentration of this element in the reactor affluent, while the magnesium concentration was lower in the effluent than in the reactor affluent. The resulting Ca^{2+} and Mg^{2+} concentrations are presented in Table 2 for the cassava processing wastewater and treated effluent for each applied organic loading rates. The Ca^{2+} content significantly increased from organic loading rate 1.54 gCOD $L^{-1} d^{-1}$ and remained constant until organic loading rate of 8.11 gCOD $L^{-1} d^{-1}$ was reached, which corresponded with the point at which

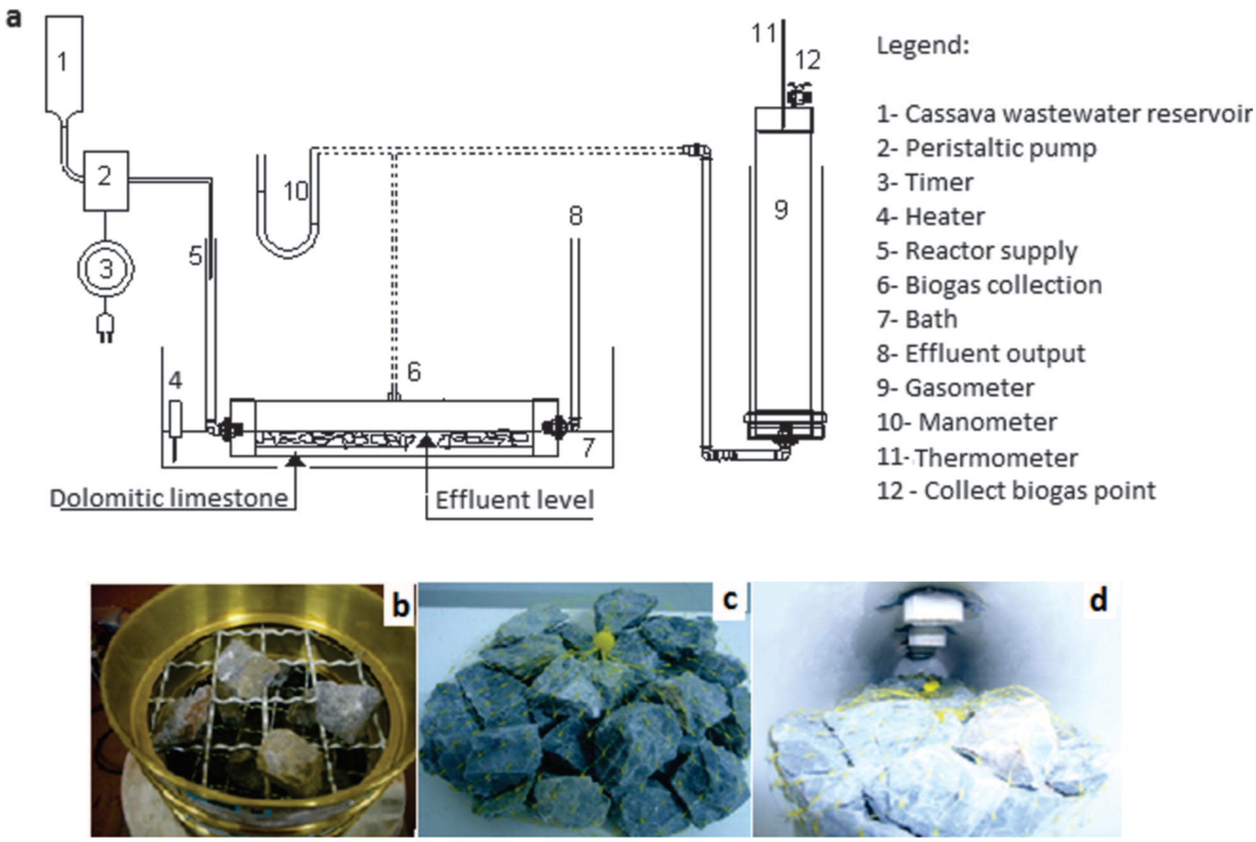

Figure 1: Diagram of the anaerobic treatment system: (a) experimental apparatus; (b) standardization process of limestone; (c) packaging of rocks in bags and (d) limestone arranged into the reactor.

the Ca content of the reactor effluent began to decrease. The greatest Mg^{2+} removal occurred at a loading rate of 14.79 gCOD L^{-1} d^{-1}.

The percentages of dry mass removed for the six sets of limestone based on their dry weights before the trial range from 2,25 to 2,65%. On average, the total weight decreased by 32 g, corresponding to an average total weight decrease of 2.51%. This result indicates the limestone wear, with consequent calcium and magnesium release, that resulted from buffering the solution and maintaining the stability of the system. The Mg^{2+} concentration in the reactor sludge at the end of this trial was 5.05 times greater than the Mg^{2+} concentration in the inoculum, and the Ca^{2+} concentration was approximately 5000 times greater than the Mg^{2+} concentration in the inoculum (Table 3). This result seems to indicate that magnesium ions are derived from limestone dissolution.

However, Ca^{2+} and Mg^{2+} ions may be toxic to bacteria. Ca^{2+} concentrations of up to 200 mg L^{-1}, between 2,500 and 4,500 mg L^{-1}, and above 8,000 mg L^{-1} stimulate, moderately inhibit, and strongly inhibit bacterial activity, respectively. While, Mg^{2+} concentrations of up to 150 mg L^{-1} stimulate bacterial activity, Mg^{2+} concentrations between 1,000 and 1,500 mg L^{-1} moderately inhibit bacterial activity and Mg^{2+} concentrations above 3,000 mg L^{-1} strongly inhibit bacterial activity (Chernicharo, 2007). In this trial, the results obtained indicated that the release of

Table 1: Compositional characterization of the cassava processing wastewater (CPW) used in the experiments

Parameter	Reference	Inoculum	CPW
COD (mgO_2 L^{-1})	APHA, 2005-5220D	23,720.95	13,331.30
pH (-)	APHA, 2005-4500A	6.91	5.37
EC (dS m^{-1})	APHA, 2005-2510B	0.61	0.58
PA (mg$CaCO_3$ L^{-1})	Chernicharo, 2007	356.67	18.64
MA (mg$CaCO_3$ L^{-1})	Chernicharo, 2007	50.00	147.56
TA (mg$CaCO_3$ L^{-1})	Chernicharo, 2007	406.67	226.20
VA (mgCH_3COOH L^{-1})	Chernicharo, 2007	60.00	621.60
VA/TA (-)	-	0.48	1.68
TS (mg L^{-1})	APHA, 1998-2540 B	16,619.33	8,292.58
TFS (mg L^{-1})	APHA, 1998-2540 E	9,702.00	1,432.88
TVS (mg L^{-1})	APHA, 1998-2540 E	6,917.33	6,859.69
Calcium (mg L^{-1})	APHA, 2005-3111A	0.17	6.94
Magnesium (mg L^{-1})	APHA, 2005-3111A	124.55	151.48
Lactic acid (mg L^{-1})	APHA, 2005-5560 B	131.64	948.46
Acetic acid (mg L^{-1})	APHA, 2005-5560 B	392.68	533.92
Propionic acid (mg L^{-1})	APHA, 2005-5560 B	888.20	nd
Butiric acid (mg L^{-1})	APHA, 2005-5560 B	180.06	1893.07

Legend: COD – Chemical Oxygen Demand; EC - Electrical conductivity; PA - Partial alkalinity; IA - Intermediate alkalinity; TA - Total alkalinity; VA - Volatile acidity; VA/TA - Volatile acidity/Total alkalinity; TS – Total solids; TFS – Total fixed solids and TVS – Total volatile solids.

Table 2: Impact of organic loading rate (OLR) on calcium and magnesium concentrations and their percent changes after treatment of cassava wastewater in an anaerobic reactor containing dolomitic limestone

OLR (gCOD L^{-1} d^{-1})	Ca^{2+} (mg L^{-1})	$Ca^{2+}_{increase}$ (%)	Mg^{2+} (mg L^{-1})	$Mg^{2+}_{remotion}$ (%)
1.23	11.55 a	34	119.87 def	23.26 ab
1.54	13.53 a	57	117.86 cdef	24.55 ab
1.84	607.60 e	7434	130.78 ef	13.66 a
2.45	595.70 e	7286	106.07 bcde	5.98 a
3.40	557.70 de	6847	142.95 ef	5.57 a
4.96	568.20 de	7015	138.62 ef	12.67 a
6.01	573.10 de	15551	142.40 ef	5.03 a
8.11	574.07 de	23702	145.70 f	6.65 a
10.14	450.10 cd	18562	87.87 abcd	37.57 ab
12.39	361.69 c	14896	80.30 abc	42.95 bcd
14.79	201.30 b	2552	64.42 a	61.40 d
16.43	332.45 c	4281	75.37 ab	48.71 cd

Values followed by the same letter in each column are statistically equal at a 95% confidence level.

Ca^{2+} and Mg^{2+} from limestone did not inhibit the anaerobic sludge at the studied conditions, since the organic matter removal remained high (Table 6).

Ribas *et al*. (2010) obtained Ca^{2+} and Mg^{2+} concentrations of 2,220 and 2,170 mg L^{-1}, respectively, in acidogenic reactor effluent for cassava flour wastewater treatment containing dolomitic limestone. Compared to the study by Ribas *et al*. (2010), the present work presents lower calcium and magnesium concentrations. However, said concentrations appear to have been adequate adequate for maintaining stable pH and VA/AT ratios. The efficiency of anaerobic digestion depends on the operational conditions of the process (Pereira *et al.*, 2009). The pH values in the reactor effluent may be considered adequate for methanogenic bacteria activity and can produce CH_4 in the range of 6.0 to 8.0 (Chernicharo, 2007). The VA/TA ratio relates to stability of the anaerobic digestion system, and must remain below 0.5 (Silva, 1977).

The pH values reactor effluent ranged from 6.52 to 6.87 throughout the trial, without statistical different between treatments. The average effluent pH (6.69) represented an increase of 1.3 times relative to the average affluent pH. The VA/TA ratio varied from 0.08 to 0.49, and the average VA/TA ratios showed statistical differences (Table 4). The low values of the VA/TA ratios resulted from the high levels of alkalinity in the system, resulting from limestone dissolution and Ca^{2+} and Mg^{2+} release. The pH and VA/TA results in this trial are similar to those obtained by other authors. Ribas (2003) observed pH values of 5.98 and 7.70 in the effluent of a methanogen reactor fed with cassava flour wastewater, which was previously stabilized with dolomitic limestone during the acidogenic phase. Oliveira (2007) obtained average pH of 6.58 in effluents of anaerobic reactor used for cassava flour wastewater treatment containing dolomitic limestone. That authors indicate that VA/TA values bigger than 0.5 resulted in the instability of the treatment systems, as shown in acidogenic reactor (1.25), methanogenic reactor (0.96 and 1.05) (Ribas, 2003) and single-phase reactor (between 0.56 and 0.82) (Oliveira, 2007). In this trial, pH and VA/TA ratio results indicated that the anaerobic system remained stable.

Table 3: Averages of calcium and magnesium concentrations in the reactor sludge at the end of the operation

Sample	calcium (mg L^{-1})	magnesium (mg L^{-1})
Inoculum	0.17	124.55
Sludge point A	601.98	482.69
Sludge point B	735.53	548.02
Sludge point C	424.34	506.79

Table 4: Impact of organic loading rate (OLR) on pH and ratio volatile acidity/total alkalinity and their changes after treatment of cassava wastewater in an anaerobic reactor containing dolomitic limestone

OLR (gCOD $L^{-1}d^{-1}$)	pH (-)	Volatile acidity/ Total alkalinity(-)
1.23	6.72 a	0.43 ab
1.54	6.87 a	0.14 ab
1.84	6.63 a	0.12 ab
2.45	6.52 a	0.09 ab
3.40	6.60 a	0.08 a
4.96	6.59 a	0.22 ab
6.01	6.87 a	0.16 ab
8.11	6.77 a	0.13 ab
10.14	6.55 a	0.24 ab
12.39	6.71 a	0.29 ab
14.79	6.80 a	0.24 ab
16.43	6.66 a	0.49 b

Values followed by the same letter in each column are statistically equal at a 95% confidence level.

Table 5: Impact of organic loading rate (OLR) on partial alkalinity (PA), intermediate alkalinity (IA), total alkalinity (TA) and volatile acidity (VA) and their averages after treatment of cassava wastewater in an anaerobic reactor containing dolomitic limestone

OLR (gDQO $L^{-1}d^{-1}$)	PA (mg $CaCO_3$ L^{-1})	IA (mg $CaCO_3$ L^{-1})	TA (mg $CaCO_3$ L^{-1})	VA (mg CH_3COOH L^{-1})
1.23	438.50 a	328.75 ab	767.2 ab	327.10 ab
1.54	731.50 abc	253.00 a	984.50 bc	134.00 ab
1.84	710.17 abc	261.75 a	971.92 bc	118.32 ab
2.45	693.08 abc	278.08 ab	971.17 bc	90.50 a
3.40	710.33 abc	340.17 ab	1,050.50 cd	80.91 a
4.96	653.30 abc	414.42 ab	1,067.80 cd	235.77 ab
6.01	949.00 bc	316.10 ab	1,265.50 de	193.00 ab
8.11	1,008.20 c	425.90 ab	1,434.10 e	185.30 ab
10.14	894.60 bc	477.20 b	1,371.80 e	330.60 ab
12.39	901.90 bc	440.20 ab	1,342.10 e	384.54 b
14.79	575.80 ab	364.60 ab	940.30 abc	223.60 ab
16.43	397.50 a	338.10 ab	735.60 a	355.00 ab

Values followed by the same letter in each column are statistically equal at a 95% confidence level.

The effluent presented high TA values that varied from 735.60 to 1434.10 $mgCaCO_3 L^{-1}$, and the TA values in the affluent varied from 195.33 to 367.83 $mgCaCO_3 L^{-1}$. The greatest TA values corresponded to organic loading rates with the greatest Ca^{2+} and Mg^{2+} concentrations, as shown in Table 2. The VA varied from 80.91 to 384.54 $mgCH_3COOH L^{-1}$, and the average VA of the effluent was 621.6 $mgCH_3COOH L^{-1}$.

As shown in Table 5, statistical differences were observed for PA, IA, TA and VA. The greatest TA values corresponded to organic loading rate with the greatest Ca^{2+} and Mg^{2+} concentrations. Buffering was inferred to result from the alkalinity derived from the release of Ca^{2+} and Mg^{2+} during limestone dissolution. These results showed that satisfactory TA values can be obtained when using limestone as an alkalizing agent in single-phase reactors. The VA levels were near the recommended range for stable reactors (100 to 300 $mgCH_3COOH L^{-1}$) (Chernicharo, 2007) and made it possible to maintain alkalinity without sudden decreases in pH.

Table 6: Impact of organic loading rate (OLR) on Total COD removal efficiency and Filtered COD removal efficiency after treatment of cassava wastewater in an anaerobic reactor containing dolomitic limestone

OLR (gDQO $L^{-1} d^{-1}$)	Total COD removal efficiency(%)	Filtered COD removal efficiency (%)
1.23	84.93	95.22
1.54	92.33	94.16
1.84	92.40	94.69
2.45	94.33	97.55
3.4	87.18	92.35
4.96	73.34	90.00
6.01	86.45	96.72
8.11	87.51	95.29
10.14	88.26	95.45
12.39	85.92	96.23
14.79	83.78	94.37
16.43	85.86	93.14

Note: Variances of the COD removal data did not show homoscedasticity. Thus, it was not possible to perform the ANOVA test and the means comparison test for this parameter.

The main indication that the starch wastewater treatment in reactor containing dolomitic limestone occurred efficiently is given by the values of organic matter removal (Table 6). Total COD removal and filtered COD removal were approximately 87% and 95%, respectively. Total COD removal results presented in Table 6 are higher than those reported by other authors who used dolomitic limestone: 53.90% (Ribas, 2003), 37 to 46% (Oliveira, 2007) and 61.95% (Ribas & Barana, 2003).

Regarding the treatment system stability, it is known that volatile fatty acids accumulation in the anaerobic reactors effluent is indicative that one or more steps of the system are being impaired. This fact reflects an instability condition, although it does not reflect an inherent deficiency in anaerobic digestion (Aquino & Chernicharo, 2005). Under real operating conditions, the volatile fatty acids concentration ranges from values close to zero to values of 2,000 mg L^{-1} or higher, which makes it difficult to define the minimum neutralizing agent dosage, with consequent additional cost (Monteggia *et al.*, 1996). In this experiment, the lactic, acetic and propionic acid concentrations in the reactor effluent were showed in Table 7.

The lowest acid concentrations in Table 7 correspond to the lowest VA values shown in Table 5 because acidity decreased as bacteria used organic acids (Leite *et al.*, 2004). The acetic acid concentrations were observed to decrease at organic loading rates equal to or above 10.14 gCOD $L^{-1} d^{-1}$, which indicated higher organic acid consumption by methanogenic bacteria. These

Table 7: Impact of organic loading rate (OLR) on lactic acid, acetic acid and propionic acid and their averages after treatment of cassava wastewater in an anaerobic reactor containing dolomitic limestone

OLR (gDQO $L^{-1} d^{-1}$)	Lactic acid (mg L^{-1})	Acetic acid (mg L^{-1})	Propionic acid (mg L^{-1})
1.23	163.80 c	286.60 c	138.60 de
1.54	117.94 bc	191.07 ab	51.75 abc
1.84	105.47 b	182.88 ab	50.92 abc
2.45	119.38 bc	190.17 ab	31.52 ab
3.40	-	170.59 a	30.53 ab
4.96	128.19 bc	269.12 bc	100.20 bcde
6.01	135.70 bc	268.10 bc	55.39 abc
8.11	131.70 bc	186.77 ab	-
10.14	113.86 b	260.16 bc	150.00 e
12.39	135.49 bc	227.90 abc	119.80 cde
14.79	117.89 bc	200.30 abc	74.60 bcd
16.43	113.36 b	170.70 a	89.40 bcde

Values followed by the same letter in each column are statistically equal at a 95% confidence level.

concentrations were not able to consume alkalinity to the point of causing drops in pH. Thus, the anaerobic system was stable during the 134 days of the test.

CONCLUSIONS

No statistical significant differences of reactor efficiency were observed among the organic loading rates applied to the system, and the pH and Volatile acidity/ Total alkalinity remained at optimum levels for the metabolic activity of methanogenic archaea.

These observations resulted from the high bicarbonate levels produced in the system, which offset the generation of volatile acidity and was attributed to the presence of calcium and magnesium ions derived from dolomitic limestone dissolution.

Considering the rapid stabilization of the treatment system at each increment of organic loading rate (12 treatments in only 134 days), smaller limestone dose should be evaluated for buffering the cassava processing wastewater.

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