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Anaerobic digestion of rice straw in presence of sulfate containing environment

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Rice straw is most abundant lignocellulose biomass in the environment. In this paper, effect of the sulfate in the anaerobic digestion of rice straw has been identified. Biodegradability of the rice straw has been assessed in terms of production of soluble compounds. The parameter such as Chemical Oxygen Demand (COD), Total Reducing Sugar (TRS), and Volatile Fatty Acids (VFA) has been analyzed to observe the biodegradability. Two set of experiments were run for the HRT of 55 days, first set where sulfate is present (Reactor R1), while second set where sulfate is absent (Reactor B1). The residual amount of COD, TRS and VFA were lesser in Reactor R1 (1851±117, 1299±148, 500±70 respectively) in comparison of Reactor B1 (3100±117, 1953±234, 750±110 respectively), within HRT of 55 days. By comparing both of results, it is revealed that the presence of sulfate were found to beneficial for digesting the rice straw under the anaerobic condition.

Keywords: Anaerobic digestion, rice straw, sulfate.

Introduction

Rice straw is most abundant lignocellulose biomass in the environment. Rice straw contains cellulose: 37%, hemicelluloses: 24% and lignin: 14%. Theoretical yield of glucose content from rice straw is 52.1%[1]. The carbohydrate content of rice straw typically involves glucose (41–43.4%), xylose (14.8–20.2%), arabinose (2.7–4.5%), mannose (1.8%) and galactose (0.4%)[4]. Study on the anaerobic digestion of any kind of lignocellulosic waste has been reported by several researchers, which are mainly focused on formation of methane from it. Apart from it they are focused on the harmful effect of sulfate on methane production, but the positive effect of sulfate on the digestion process is rarely reported. In this paper, anaerobic digestion of rice straw in presence and absence of sulfate has been studied.

Many of the studies, has paid a more attention on the competition between the SRB and other bacteria (methane forming archea) during the anaerobic digestion[10,11]. Although sulfate has a positive effect on substrate consumption during the digestion process and to produce the sulfide as a by-product. During the entire process, SRB (sulfate reducing bacteria) plays an important role to consume and oxidize the substrate, with the faster rate[2,7].

In the digestion process SRB (sulfate reducing bacteria) and MPB (methane producing bacteria) competes for the carbon source[6] and produces the sulfide[12]. Generated sulfide due to microbial reduction are beneficial for the anaerobic digestion process[3] and several other purpose such as metal precipitation.

Material and methods:

Preprocessing of rice straw were done by cutting, milling, sieving. The synthetic wastewater was prepared by addition of the following components (g/L): KH_2PO_4, 0.5; K_2HPO_4, 0.1; $NaHCO_3$, 0.65; NH_4Cl, 0.1, while trace metal were added at the rate of 1 ml/L with initial concentration (g/L) of $CaCl_2.2H_2O$, 0.05; $NaMo_2.H_2O$, 0.03; KCl, 0.05; $CoCl_2.6H_2O$, 0.02; $MgCl_2.6H_2O$, 0.05; $NiSO_2.6H_2O$, 0.01; sodium ascorbate, 0.05 and sodium thioglycollate, 0.05. Two set of experiments were run for the HRT of 55 days, first set where sulfate is present (Reactor R1), while second set where sulfate is absent (Reactor B1). Reactor R1 has been run with initial sulfate concentration of 1652±90 mg/L. No addition of sulfate was done in Reactor B1, around 200±30 mg/L of sulfate was already present in the sludge. Configuration of batch reactor is shown in Fig. 3. For maintaining the anaerobic condition, nitrogen gas has been supplied at the interval of 5 days. The concentration of Chemical Oxygen Demand (COD), sulfate, and sulfide has been analyzed using the standard

method. Total Reducing Sugar (TRS), and Volatile Fatty Acids (VFA) has been analyzed using method suggested by DNS reagent[7] and direct titration method[9].

Results and discussion

Reactor has been monitored for 55 days at the interval of 5 days. The concentration of Chemical Oxygen Demand (COD), Total Reducing Sugar (TRS), and Volatile Fatty Acids (VFA) has been analyzed. The change in the COD, VFA and pH during the entire day of operation are confirming towards the degradation of rice straw in simple monomers, which is done by the SRB and other microorganism.

In Reactor R1, the concentration of COD, TRS and VFA was found to be highest at 20 days which was around 3886±153 mg/L, 2699±111 mg/L and 1057±56 mg/L, respectively (Fig. 1 and Table 2). In Reactor B1, the concentration of COD, TRS and VFA was found to be highest at 20 days which was 5300 ± 153 mg/L, 3700 ± 156 mg/L and 1340 ± 40 mg/L, respectively (Fig. 1 and Table 1). The residual amount of COD, TRS and VFA (at HRT of 55 days) were lesser in Reactor R1 (sulfate added) in comparison to Reactor B1 (without added) (Fig. 1 and Table 2). This indicates toward that presence of electron acceptor (sulfate) is responsible for the consumption of most of organic compounds. As there is presence of sulfate (in Reactor R1), which has promoted the growth of SRB, and wherever SRB (sulfate-reducing bacteria) and other microorganism (MPA - methane-producing bacteria) remains present, they always compete for carbon source[10,11]. However, in sulfate-rich environment, SRB outcompete with other microorganism, and produces the sulfide as a by product during the sulfate reduction process. By comparing both of reactor, it is revealed that the presence of sulfate were found to beneficial for digesting the rice straw under the anaerobic condition.

In both of the cases, the increment in COD and VFA (Figs. 1 and 2) has been noticed at around 15–20 days, which was

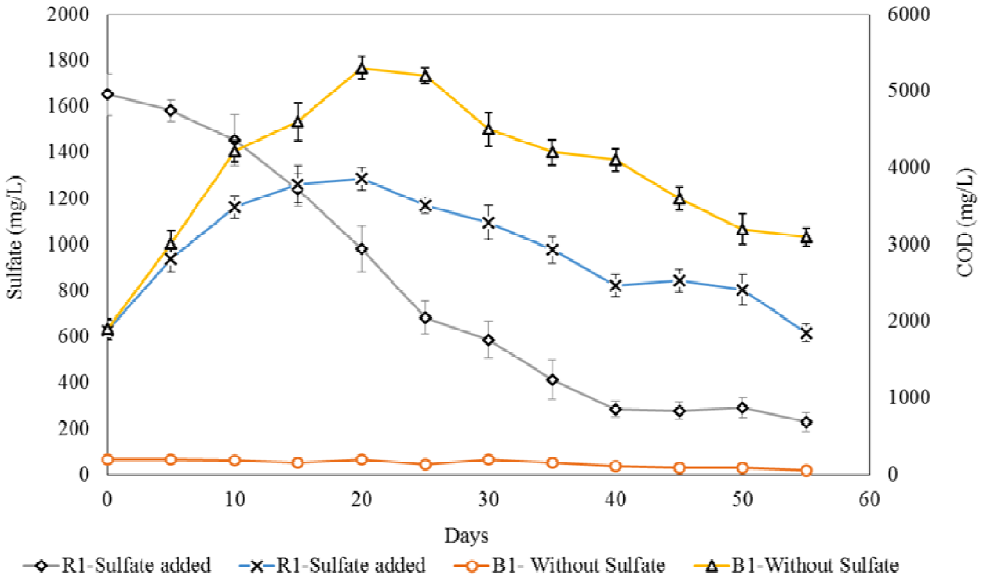

Fig. 1. Changes in sulfate concentration and COD with days.

Table 1. Changes in concentration with days in Reactor B1 (Without sulfate)

Days	COD (mg/L)	TRS (mg/L)	VFA (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	BOD:COD	pH
0	1900±126	1456±103	316±45	200±30	90±30	0.4±0.01	7.5±0.04
15	4600±246	3200±134	1404±96	140±40	110±45	0.5±0.02	6.3±0.16
20	5300±123	3700±156	1340±40	90±45	70±50	0.6±0.04	6.5±0.3
55	3100±117	1953±234	750±110	70±40	50±43	0.4±0.02	7.8±0.07

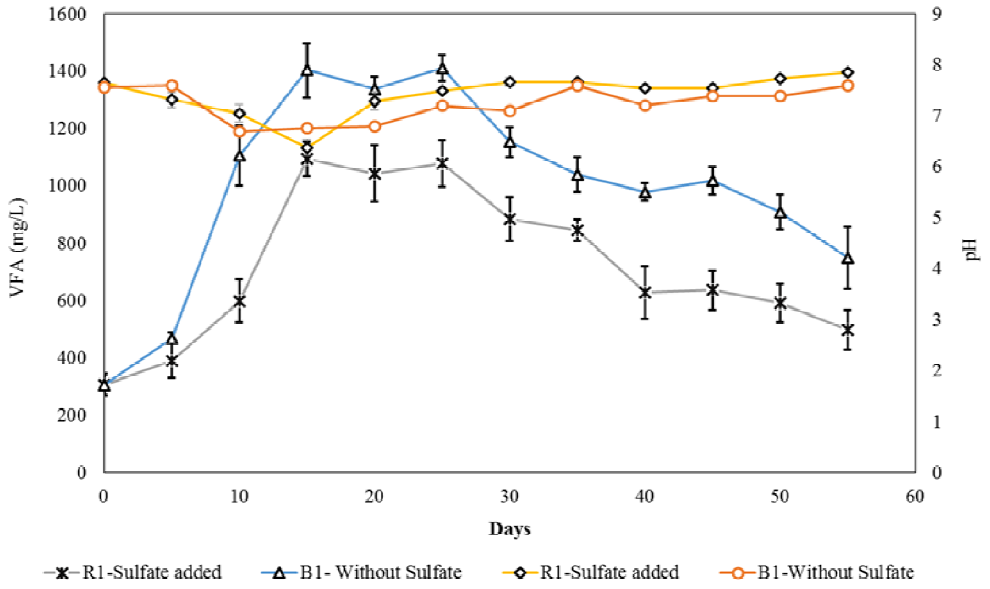

Fig. 2. Changes in VFA concentration and pH with days.

Table 2. Changes in concentration with days in Reactor R1 (Sulfate added)

Days	COD (mg/L)	TRS (mg/L)	VFA (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	BOD:COD	pH
0	1881±126	1316±103	307±37.5	1652±90	90±30	0.4±0.02	7.6±0.2
15	3782±246	2647±123	1095±30	1237±73	190±30	0.64±0.01	6.4±0.4
20	3886±153	2699±111	1057±56	980±99	280±50	0.59±0.03	6.3±0.17
55	1851±117	1299±148	500±70	226±40	112±43	0.5±0.03	7.8±0.2

possibly due to breakdown of lignocellulosic compounds of rice straw. Beyond 15–20 days the reduction in the concentration were observed, may be due to consumption of organic compounds by micro-organism such as SRB and other population present in the wastewater.

In Reactor R1 (from Fig. 2), the dropdown in the pH was observed from 7.6±0.2 to 6.3±0.17 which reflects towards the hydrolysis process (formation of short chain fatty acids) in between 0 to 20 days[5]. After 15–20 days, the consumption of VFAs has been started due to this reason again increment in the pH has been observed, which was 7.8±0.2 (at 55 day). Similar trend were noticed in Reactor B1 (from Fig. 2). The BOD:COD ratio has been reflected in Tables 1 and 2 for Reactors B1 and R1 respectively.

From Fig. 1, sulfate concentration has been reduced from 1652±90 mg/L (at 0 day) to 226±40 mg/L (at 55 day), in

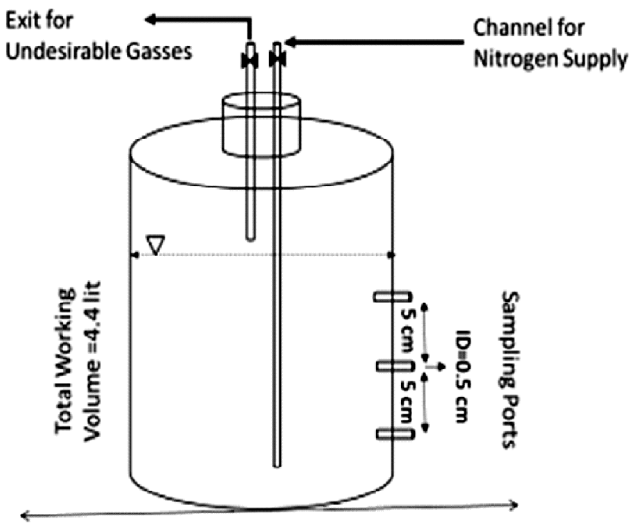

Fig. 3. Schematic diagram of batch reactor.

Reactor R1. However, in Reactor B1 (no addition of sulfate), the concentration of sulfate is found in the range of 200± 25 mg/L (at 0 day) to 55±25 mg/L (at 55 day). In Reactor R1, change in sulfide concentration was also noticed from 90±30 mg/L (0 day) to 280±50 (20 day) and finally 112±43 (at 55 day) form Table 2.

Conclusions

Presence of sulphate were found to be beneficial for anaerobic digestion of rice straw. During the entire process SRB has an important role, towards the substrate degradation and its utilisation. The addition sulphate is not only beneficial for substrate oxidation but also, it is useful for production of sulphide, which can be further utilised for metal precipitation. The addition of sulfate has shown the excellent capability for substrate degradation, according to the results obtained in this study.

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