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Treatment of sugarmill effluent and simultaneous production of ethanol: Effect of pH and quantity of seed sludge

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Abstract

India is the largest producer of sugar and generates 0.16 – 0.76 m^3 of wastewater for every ton of crushed cane. In this paper, the effect of pH and seed sludge on simultaneous treatment and ethanol production from a sugar mill wastewater using anaerobic sludge was investigated. The sugar mill wastewater had following composition: pH (6.69 ±0.45), reducing sugar (5 – 6.83 mg/mL), chemical oxygen demand (5000 – 8000 mg/L), total nitrogen (22.73 – 22.97 mg/L), and NPOC (1589 – 1647 mg/L). Seed sludge (10 – 50 % v/v) and pH (4 - 5.5) were varied in this study. Organic carbon removal was determined by analyzing non-purgeable organic carbon (NPOC) in a TOC liquid analyzer. Fermentation process was carried out for 24, 48, 72, 96 and 120 h. Maximum ethanol yield of 0.00133 L/L of sugarcane wastewater was obtained at pH of 5.5 using 10 % v/v seed sludge. Moreover, 46 % NPOC removal was achieved under this condition. India produces 900000 m^3 of sugarcane wastewater annually. According to the present study, it is possible to produce 1184 m^3 of ethanol per year from sugarcane wastewater by treating the wastewater in anaerobic reactor under an acidic condition. However, detailed pilot study is required to determine the economic and technical feasibility.

Keywords: Anaerobic, ethanol, pH, sugarmill wastewater, NPOC, COD, TSS

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1. Introduction

Renewable energy, environmental pollution, and climate change have been the topics of intense discussion in recent years [1]. With ever increasing energy demand and depleting fossil fuel reserves, fuel cost is likely to increase in the future. Understandably, there is an increased attention towards investigating the prospects of synthesizing fuels (e.g. ethanol) from alternate sources. Sugarcane is the main feedstock for fuel production among the energy crops in India. India ranks second in the world in terms of sugarcane production. A recent survey mentioned that India produces 352 million tons of sugarcane every year [3]. The ethanol production from sugarcane requires pretreatment process to recover cellulose and hemicellulose through biological processes. However, being a food crop, biofuel synthesis from sugarcane is not encouraged. It is estimated that Indian sugar mills generate 0.16 – 0.76 m^3 of wastewater for every ton of crushed sugarcane [4]. Sugarcane wastewater contains carbohydrates, grease, sulfates, chlorides and heavy metals [5]. Sugarcane wastewater can also be utilized for biofuel production due to its carbohydrate content. E10 or 10 % ethanol can be blended with petrol which contributes to reduction in emission of pollutant and Greenhouse gas [6]. This study focusses on utilization of the carbohydrate content of a sugarcane wastewater for synthesis of ethanol. The objective is to study the effect of pH and seed sludge on simultaneous treatment and ethanol production from sugarcane wastewater.

2. Materials and Methods

2.1. Collection and characterization of sample

Sugar mill wastewater was collected from Gayathri Sugars Pvt. Ltd, Nizamabad, Telangana. Collected wastewater was characterized for wastewater parameters. Wastewater was characterized for pH, total suspended solids, chemical oxygen demand and alkalinity following standard protocols [7]. Reducing sugar was quantified using 3, 5 dinitrosalicylic acid [8]. Total carbohydrate was determined using phenol – sulphuric acid method [9]. NPOC were determined using TOCL analyzer. After characterization, wastewater was stored at 4^oC until further study. Anaerobic sludge was collected from a UASB-based common effluent treatment plant situated at Amberpet, Telangana. The sludge was kept under anaerobic condition by purging with nitrogen gas [10].

2.2. Quantitative analysis of ethanol

Ethanol was determined quantitatively using Gas chromatograph equipped with computer integrator software Compass CDS version 3.0 and an FID (Flame Ionization Detector) detector. The flow rates of high pure hydrogen and zero air were set at 30 and 300 mL/min, respectively. The temperatures of the injection port and the FID detector were set at 225ºC, and 285ºC, respectively. High purity Helium (He) at 2 mL/min was used as the carrier gas. A BR-SWax separation column (FS 30 m, 0.25 mmID, 0.25 μm df) was used. The oven temperature was set initially at 45ºC for 2 min and then increased to the final temperature of 240ºC at the rate of 45ºC/min. Injection volume was limited to 1 μL. Splitless injection mode was selected.

2.3. Experimental setup

2.3.1 Effect of pH on fermentation:

Wheaton bottles (125 mL) were used as test reactors. To each bottle 25 % v/v of anaerobic sludge and 75 % v/v of sugarmill wastewater was added. The pH was adjusted to 4, 4.5, 5, 5.5 using 1 N H_2SO_4 and 1 N NaOH. Fermentation process was carried out at 30°C in an unstirred condition. Samples were withdrawn after 24, 48, 72, 96 and 120 h and analyzed for ethanol.

2.3.2 Effect of seed sludge on fermentation:

Different seed sludge volumes (10, 20, 30, 40 and 50 % v/v) were tried in this study. Fermentation was carried out at 30°C in an unstirred condition. Samples were withdrawn after 24, 48, 72, 96 and 120 h and analyzed for ethanol.

3. Results and Discussion

3.1. Characterization of wastewater

Sugar mill wastewater had a light brown colour. The chemical characteristics of the sugarmill wastewater are shown in table 1 and compares well with similar analysis done elsewhere [11-12].

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3.2. Effect of pH on ethanol synthesis

The effect of pH on ethanol production is shown in Fig. 1. Ethanol production peaked between 24 and 48 hours at all the pH. Maximum ethanol concentration, 989 mg/L, was observed at pH 5.5. Ethanol concentration decreased steadily thereafter, possibly due a slow conversion of ethanol into biogas. Biogas analysis was not carried out in this study.

3.3. Effect of seed sludge volume on ethanol synthesis

The pH was fixed at 5.5 in this study. Different quantities seed sludge -10, 20, 30, 40 and 50 % v/v- was added to the bottles and incubated at 30 ^{o}C in an incubator. Fig 2 shows the effect of seed sludge volume and time on ethanol concentration. Maximum ethanol yield was observed at 24 hours from the beginning of the experiment in all the cases. Highest concentration of ethanol, 1032 mg/L, was observed using 10% seed sludge volume. A reduction in ethanol yield at higher sludge volume was possibly due to a larger methanogenic biomass in the test reactors which transformed ethanol into biogas. However, biogas analysis was not done in this study.

3.4 Wastewater treatment

Treatment efficiency of wastewater was determined by finding the percentage removal of COD, NPOC and TSS. It was observed that there was a constant decrease in COD from 6400 to 3776 mg/L in a period of 120 h (5 days). COD removal was 28% at the end of 24 h and 41% at the end of 120h. About 46% of NPOC was removed in the first 24 hours. NPOC removal at the end of 5 days was 70%. Initially the TSS of sugarmill wastewater was 4520 mg/L. there was 30 % removal of TSS after 24 hours and at 120 hours 55 % removal was achieved. The COD, NPOC, and TSS removal curves plateaued after 5 days of experimental run and shown in Fig. 3.

4. Conclusion

Simultaneous treatment and ethanol production from sugarmill wastewater were investigated. It was observed that maximum ethanol yield of 1032 mg/L occurred within the first 24 hours of the study at pH 5.5 using 10 % v/v of seed sludge. Thereafter, ethanol yield decreased possibly due to a gradual conversion to biogas. On basis of this study, it is concluded that it is possible to produce 1184 m^3 of ethanol from 900000 m^3 of sugarcane wastewater that is generated annually. However, detailed pilot study is required to determine the economic and technical feasibility. About 41% of COD, 70% of NPOC, and 55% of TSS removal could be achieved in an acidic (pH 5.5) anaerobic condition.

5. Acknowledgement

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Figures

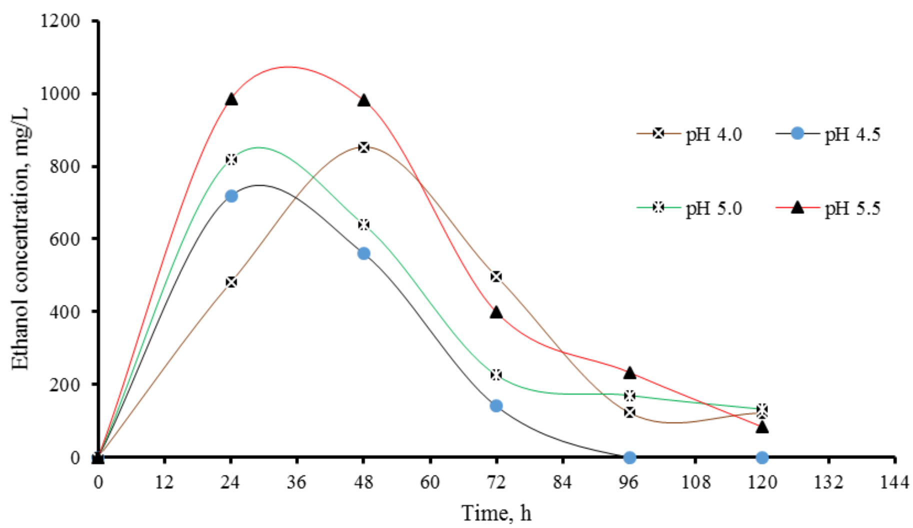

Figure 1. Effect of different pH on ethanol production from sugarmill wastewater

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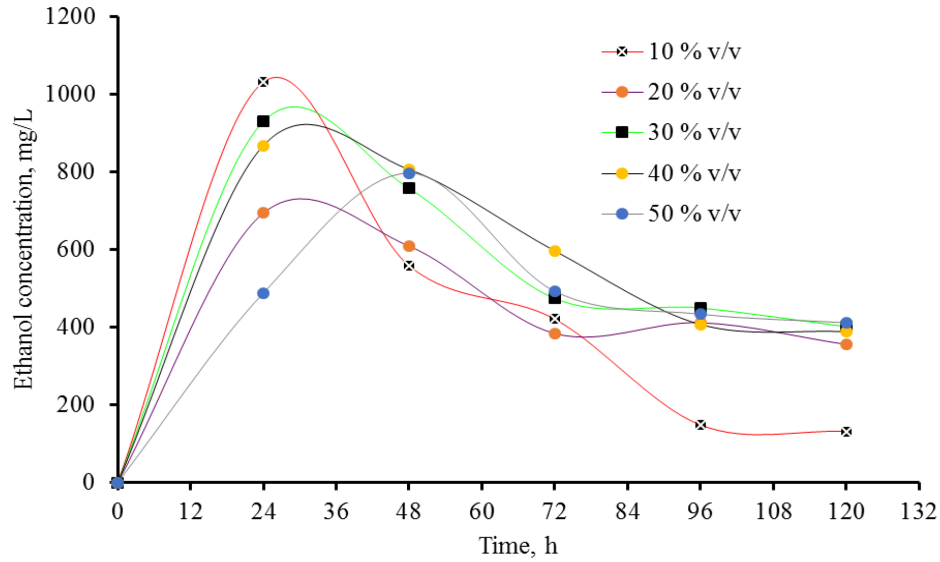

Figure 2. Effect of different percentage volume of sludge biomass on ethanol production from sugarmill wastewater

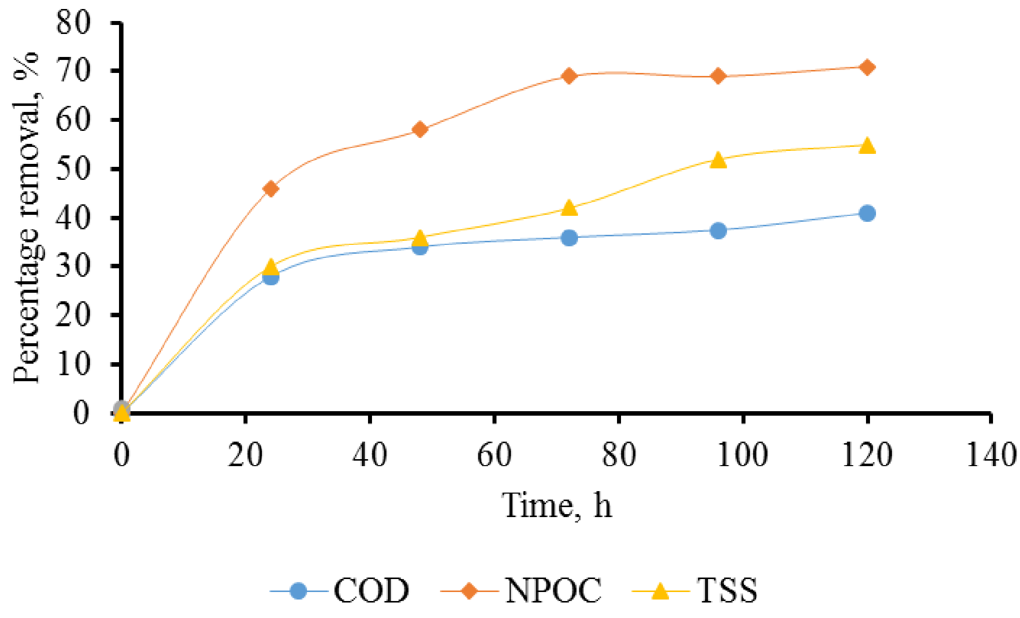

Figure 3. Percentage removal for parameters of sugarmill wastewater during simultaneous treatment and ethanol production

Table 1 Sugarmill wastewater characteristics

Parameters	Units	This study	[11]	[12]
pH		6.69	4.5	7
Colour	mg/mL	Light brown	-	Dark brown
Reducing Sugar	mg/mL	5.34	-	-
Total Carbohydrate	mg/mL	9.3	-	-
TSS	mg/L	4500 - 4520	288 - 5030	-
COD	mg/L	5000 – 8000	799 - 10640	8339 - 9033
TN	mg/L	22.73 – 22.97	20 – 43	-
NPOC	mg/L	1636	-	-
Alkalinity	mg/L	1650 - 1755	-	-

TSS – Total Suspended Solids; COD – Chemical Oxygen Demand; TN – Total nitrogen; NPOC – Non Purgeable Organic Carbon.