Enrichment of Bio-components Release with Effective Methane Generation from Prefragmented Paper Industry Wastewater using Homogenizer Method

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Abstract

Biodegradability is the major concern for methane generation because complex bio-components as key factors for speeding hydrolysis steps. In this study, methane gas generation potential of paper industry wastewater (PWW) was studied using homogenizer as mechanical prefragmentation method. Initially, homogenizer was performed by varying prefragmentation time and rpm. At optimum prefragmentation time (50 min) and rpm (20000), homogenizer method obtained 3912 mg/L of bio-components extricate during PWW sample prefragmentation study. Also, maximal of lysification rate (21 %) and suspended solids (SPD) reduction (18 %) were obtained at 15748 kJ/kg TS homogenizer specific energy. Then, the prefragmented and control samples were subjected to methane assay. Homogenizer mediated PWW fragmented sample got higher methane generation (141 mL/g VS) than control sample (38 mL/g VS). Thus, homogenizer mediated prefragmentation method helps
to lessen the wastewater generation by enriching methane production with significant extricate of bio-components at commercial scale.

*Keywords:* Paper industry, Wastewater, Homogenizer, prefragmentation, specific energy, methane generation

1. Introduction

Paper industry turnover occupy 5 % of GDP growth of developing countries by generating million tons of paper and paper products for daily usage and also, harming the ecological sources by liberating of non-treated wastewater [1]. The expulsion of non-treated wastewater to the nearby natural sources causing trouble to the ecological balance and therefore, developing countries make amendments in environmental act for avert the illegal disposal of wastewater and to meet the wastewater discharge limits[2,3]. Anaerobic digestion (AD) is a microbial degradation process by escalating methane production by supply of bio-components from PWW sample to the methanogens. Nevertheless, energy efficient methane generation from PWW sample is constrained because occurrence of complex biopolymer leads to ineffective hydrolysis process [4,5]. Thus, PWW sample prefragmentation is necessary to overwhelmed the hydrolysis limitation by attaining the effective bio-components extricate. Numerous PWW sample prefragmentation studies were described namely mechanical (microwave, disperser, electrolysis and sonication), chemical (chemical surfactants, biosurfactants, sulphuric acid and ammonium nitrite) and biological (microbes, single/multi hydrolytic enzymes) [6-10]. Among them, mechanical mediated prefragmentation method has potential with higher bio-components extricate during the course of PWW prefragmentation.

Homogenizer is a mechanical method which primarily applicable for blending of particle or ingredients to obtain a fine texture especially in food processing industry, cosmetics and pharma industry [11]. Later, homogenizer is well known for wastewater and sludge biomass
fragmentation through a substantial bio-components extricate. During prefragmentation, the biomass sample was distributed to the homogenizer top position by axial effort. Then, the fragmented biomass sample was dragged towards the homogenizer slit by radial effort. Due to the function of axial and radial effort, shear force is created which resulting in an effectual biomass bound cellsdistraction leading to bio-components extricate [12]. The merits of homogenizer method compared to other prefragmentation methods are flexible operation, no chemical reaction, hike the biomass components extricate and high prefragmentation efficacy. The above literature analysis accomplishes that no research work has been reported the impact of homogenizer method on PWW sample for enriching methane generation through a substantial bio-components extricate. Therefore, the crucial objectives of the current study are to i) optimize homogenizer prefragmentation time and rpm for bio-components extricate ii) appraise the methane generation potential of homogenizer prefragmented PWW sample and control sample (raw PWW sample) iii) find the kinetic factors (regression coefficient and methane production rate) of methane data of homogenizer prefragmented PWW sample and control sample by fitting with Gompertz equation.

2. Materials and Methods

2.1 Collection and characterization of PWW sample

PWW sample was derived from aeration tank of paper industry wastewater treatment plant, located at TNPL karur, Tamilnadu. The collected PWW sample was aerated to ameliorate microbial activity and then, stored in deep freezer (4 °C) for further usage in PWW sample prefragmentation study. PWW sample characteristics were done as per APHA standard steps [13, 14] and is as follows pH-7.3 ± 0.3, Cellulose (% TS)-20, Soluble carbohydrate-190 ± 18 mg/L, Chemical oxygen demand (COD)-20149± 156 mg/L, Soluble COD- 210± 35 mg/L, and Total solids (TS)-27582 ± 84 mg/L.
2.2 Homogenizer mediated prefragmentation of PWW sample

Homogenizer (Lark PVT, India) is one of the shearing device used for PWW sample prefragmentation by disruption of complex bio-components into a simpler bio-component.

For PWW fragmentation, 1000 mL of PWW sample was taken in 2 L double walled reactor and temperature was maintained at 50 °C [11] by hoard of cooled water from chiller. Then, the influence of homogenizer prefragmentation time (0 to 120 min) and rpm (1000 to 30000) were examined on PWW for bio-components extricate. Homogenizer mediated prefragmentation of PWW sample was performed thrice.

2.2.1 Lysification rate

Lysification rate (%) was evaluated using Equation (1)

\[
\text{Lysification rate} \% = \left( \frac{SCOD_p - SCOD_i}{TCOD_i - SCOD_i} \right) \times 100
\]  

(1)

Where

SCODp denotes SCOD of prefragmented PWW (mg/L),
SCODi indicates SCOD of PWW before prefragmentation (mg/L),
TCODi implies total COD of PWW before prefragmentation (mg/L)

2.2.2 SPD reduction

SPD reduction (%) was determined by using Equation (2):

\[
\text{SPD reduction} \% = \left( \frac{SPD_i - SPD_o}{SPD_i} \right)
\]

(2)

Where

SPD_i – SPD attained before PWW prefragmentation,
SPD_o – SPD acquired after PWW prefragmentation

2.3 Methane assay of homogenizer prefragmented PWW and control samples

Methane assay was done with substrates namely control (non-treated) and homogenizer prefragmented PWW sample in 1L capacity digesters and labelled as ME1 and ME2 respectively. For digestion conditions, seed sludge (anaerobic digested sludge) and substrates
were added in the proportion of 25 % and 75 % in each digester as stated by Sethupathy et al. [15]. Prior to methane assay, the pH of substrates was maintained at 7 to 7.5. Then, nitrogen gas sprayed for 20 sec to eradicate oxygen presence in the digesters. The digesters were sealed and placed in orbital shaker (temperature- 35-37 °C, rotation speed: 100-120 rpm) for 25 days [16]. The generated methane gas was measured by sterile syringe plunger displaced technique. Methane generation and its kinetics of substrates were evaluated using Gompertz Equation (3)

$$MG_h(t) = m \times \exp\{-\exp\left[\frac{MP_h \times e}{m} (L - y) + 1\right]\}$$

Where $MG_h$-cumulative methane produced (mL), $y$- digestion time (days) $m$- methane production potential (mL), $MP_h$-maximum methane production rate (mL/d), $L$ - inactive phase (days).

3. Results and Discussion

3.1 Influence of homogenizer prefragmentation time and rpm on PWW sample for bio-components extricate

Figure 1 shows the influence of homogenizer prefragmentation time and rpm on bio-components extricate. The configuration for bio-components can be splitting into accelerate step and slothful step. In the accelerate step, bio-components extricate was increased steadily with varying prefragmentation time from 0 to 50 min. Maximal of bio-components extricate was found to be 3912 mg/L at 50 min of prefragmentation time. In the slothful step, paltry rise of bio-components extricate was noted with varying prefragmentation time from 60 to 120min. Also, the impact of rpm on bio-components was examined. During PWW prefragmentation, steadyupsurge of bio-components extricate was noted with varying rpm from 1000 to 20000 rpm. Beyond 20000 rpm, paltrysurge in bio-components extricate from
PWW sample was found. Therefore, prefragmentation time (50 min) and rpm (20000) were decided as optimal conditions for homogenizer mediated prefragmentation method.

![Graph showing the influence of homogenizer prefragmentation time and rpm on PWW sample for biocomponents extricate](image)

**Figure 1** Influence of homogenizer prefragmentation time and rpm on PWW sample for biocomponents extricate

### 3.2 Impact of homogenizer specific energy on lysification rate and SPD reduction

Figure 2 indicates the impact of homogenizer specific energy on lysification rate and SPD reduction. From Figure 2, it is seen that both the sketch of lysification rate and SPD reduction upsurge with upsurge in homogenizer specific energy. The tendency of lysification rate and SPD reduction can be splitting into augmentation phase and inert phase. In augmentation phase, lysification rate and SPD reduction were augmented quickly with varying homogenizer specific energy from 784 to 15748 kJ/kg TS (prefragmentation time ≤ 50 min). At 15748 kJ/kg TS, the maximal of lysification rate and SPD reduction were espied to be 21% and 18% respectively. In inert phase, no major acceleration in lysification rate and SPD reduction were espied with varying homogenizer specific energy from 18376 to 30912 kJ/kg TS (prefragmentation time ≥ 50 min). Thus, these results exposed that 15748 kJ/kg TS specific
energy had noteworthy effect on lysification rate and SPD reduction in homogenizer mediated prefragmentation method.

![Graph showing impact of homogenizer specific energy on lysification rate and SPD reduction.](image)

**Figure 2.** Impact of homogenizer specific energy on lysification rate and SPD reduction

**3.3 Methane generation potential of homogenizer prefragmented PWW and control samples**

Methane generation potential of control and homogenizer prefragmented PWW sample were gauged and is espied in Figure 3. From Figure 3, methane generation was augmented slothfully from 0 to 5 days of digestion time in control and homogenizer prefragmented samples. For digestion time from 5 to 19 days, the microbial energetic phase was described in which methane production surged rapidly which depicts that methanogens microbes utilize the liquefied bio-components effectuaily from PWW sample. At 19th day of digestion, homogenizer method got a maximal methane generation (141 mL/g VS) compared to control sample (38 mL/g VS). It indicates that oxidizing effect of free radicals, shear force and thermal effect were evolved from cavitation bubbles of homogenizer method which leads to weakening complex bio-components cell structure and splitting cell matrix, resulting in effective liquefied bio-components extricate.
Figure 3. Methane generation potential of homogenizer prefragmented PWW sample and control sample

Then, methane generation data of homogenizer and control samples were fitted with Gompertz Equation (3) for predicting regression coefficient ($z^2$). $z^2$ value was noticed to be 0.9951 (homogenizer) and 0.9248 (control samples) which reveals the best fitness methane data with Gompertz model [17,18]. $MP_h$ was measured respectively to be 12.1 and 2.9 (mL/g VS d) for homogenizer method and control samples. The above results revealed that homogenizer prefragmented PWW sample got higher methane production than control samples.

4. Conclusion

Methane generation potential of PWW sample was appraised using homogenizer mediated prefragmentation method. Initially, homogenizer method proceeded in which higher bio-components extricate from PWW sample was described by optimizing prefragmentation time and rpm. Also, homogenizer method demanded 15748kJ/kg TS specific energy for attaining maximal lysification rate and SPD reduction. Then, methane assay was executed in which
prefragmented method (homogenizer) attained 141 mL/g VS of methane generation than control sample. Moreover, the outcomes of homogenizer method to be used to explore the energy reduction by coupling sole homogenizer with other chemical / biological method for effective methane gas generation at large scale.

References


