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Effect of deflocculation on the efficiency of disperser induced dairy waste activated sludge disintegration and treatment cost

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HIGHLIGHTS

- Chemo mediated disperser pretreatment was an innovative approach.
- 0.04 g/g SS of sodium dodecyl sulphate enhanced deflocculation of sludge matrix.
- Chemo mediated dispersion pretreatment enhances solubilisation at 5013 kJ/kg TS.
- Hydrolysis and biogas production potential was improved in deflocculated sludge.
- Deflocculated sludge showed net energy savings of 43% during cost analysis.

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ABSTRACT

Excess sludge disintegration by energy intensive processes like mechanical pretreatment is considered to be high in cost. In this study, an attempt has been made to disintegrate excess sludge by disperser in a cost effective manner by deflocculating the sludge using sodium dodecyl sulphate (SDS) at a concentration of 0.04 g/g SS. The disperser pretreatment was effective at a specific energy input of 5013 kJ/kg TS where deflocculated sludge showed higher chemical oxygen demand solubilisation and suspended solids reduction of 26% and 22.9% than flocculated sludge and was found to be 18.8% and 18.6% for former and latter respectively. Higher accumulation of volatile fatty acid (700 mg/L) in deflocculated sludge indicates better hydrolysis of sludge by proposed method. The anaerobic biodegradability resulted in higher biogas production potential of 0.522 L/(g VS) for deflocculated sludge. Cost analysis of the study showed 43% net energy saving in deflocculated sludge.

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1. Introduction

Disposal of dairy waste water represents a major problem. Numerous effective attempts have been made to resolve this problem in which the activated sludge process (ASP) is the mostly used biological treatment process ever (Raj et al., 2013). The production of large amounts of excess sludge which is also called as waste activated sludge (WAS) is the major drawback of ASP. Besides, the production of huge amounts of WAS hinders the efficient operation of treatment units. Therefore, much attention in terms of both environmental and economical aspects has been focused on the sludge treatment process for both reducing the amount of sludge produced and improving the stabilisation degree of sludge (Sahinkaya and Sevimli, 2013). Anaerobic digestion of sludge is a promising technology, which can achieve the objective of sludge degradation and energy (Uma et al., 2013). Anaerobic degradation can be achieved through several stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Generally, the hydrolysis is the rate limiting step in the anaerobic sludge digestion, because the extracellular polymeric substances (EPS) and microbial cells are recalcitrant to the direct hydrolysis (Sheng et al., 2012) .The biodegradability of the sludge can be improved by a variety of pretreatment methods such as mechanical, thermal, chemical and biological.

Among these methods, mechanical pretreatment of sludge like dispersion has been considered effective for cell disruption. Dispersion is the dissolution and diffusion of a solid, liquid or gaseous phase in a continuum that is not consolute with that phase. Of late, this has been reported as a sludge pretreatment method, which changes both the rate and extent of sewage sludge degradation

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in the anaerobic digestion process. It was mainly developed for stabilisation of food and dairy emulsions, and has opened up more and more new application areas (Rai and Rao, 2009). This is generally based on the disruption of microbial cell wall and the release of cytoplasm into liquid phase by functions of pressure gradient, cavitation, turbulence, impingement, shear stresses and extensional shear. It has several advantages in comparison to other sludge disintegration methods, i.e. no chemical changes or denaturing during cell lysis, easy operation, and high lysis efficiency. The high-energy requirement in dispersion treatment can be reduced by combining with other treatment methods based on different mechanism of action that could allow obtaining higher disintegration (Uma et al., 2012a). Extracellular polymeric substances (EPS) are secreted by microorganisms, play an important role in bioflocculation process by interacting with the solids (Kavitha et al., 2013). Hence it is essential to remove the EPS before pretreatment to reduce the organic solids. Based on these reports, in the present study, to increase the effectiveness of the mechanical pretreatment, EPS were removed with the surfactant, Sodium dodecyl-sulphate (SDS). As a result of removing EPS with SDS, the adsorbed protein, carbohydrate and organic materials on sludge matrix got released enhancing the subsequent pretreatment. So far, literature about the effect of SDS on EPS removal followed by disperser pretreatment has been hardly reported. Thereby, the main objectives of the present work is (1) to provide more insights into the disintegration of sludge by the phase separated chemo mediated dispersion pretreatment (2) to accelerate the sludge enzyme activity at lower concentration of SDS (3) to examine the influences of chemo mediated dispersion pretreatment on subsequent anaerobic degradability for enhanced biogas production and (4) to assess the economic feasibility of pretreated sludge.

2. Methods

2.1. Sludge sampling and characterisation

Dairy waste activated sludge was sampled from Aavin dairy effluent treatment plant at Madurai. Samples were collected and stored at 4 °C. The characteristics of the raw sludge were as given in Table 1.

2.2. Optimisation of SDS dosage for removal of EPS

The SDS dosage optimisation was performed in thirteen conical flasks containing 100 mL sludge and SDS dosage in the range of 0.003–0.09 g/g SS were incubated for 1 h. After incubation, the samples were collected and centrifuged at 10,000*g* for 15 min. The pellet was discarded. The supernatant was filtered through 0.45 μm cellulose acetate membrane to get the cell free soluble EPS. The obtained soluble EPS were biochemically characterised.

Table 1
Initial characteristics of dairy WAS.

1sS. No.	Parameters	Values
1	Total solids	12,560 ± 500 mg/L
2	Suspended solids	7000 ± 200 mg/L
3	Volatile solids	5600 ± 100 mg/L
4	TCOD	10,000 ± 260 mg/L
5	SCOD	400 ± 10 mg/L
6	pH	6.91
7	Soluble protein	72.6 ± 5 mg/L
8	Soluble carbohydrate	6.1 ± 0.5 mg/L
9	DNA	3.2 ± 0.1 mg/L

2.3. Dispersion pretreatment

Sludge disintegration was carried out using a disperser (IKA T25 Ultra Turrax Digital disperser), which is a high-speed shearing device to disperse large solids into small particles. A series of experiments were performed at different working rpm in the range of 4000–24,000 for the optimised SDS dosage of 0.04 g/g SS with a sludge volume of 500 mL in order to enhance solubilisation of particulate material. The experiments were carried out for both flocculated (without EPS removal and treated with disperser alone) and deflocculated (EPS removed and pretreated with disperser) sludge in order to study the efficiency of dispersion pretreatment individually and synergistically. Moreover, the effect of this pretreatment mainly depends on treatment time, and it was evaluated by taking samples at different times (15–180 min).

2.4. Anaerobic fermentation of WAS

To explore the effect of deflocculated and disperser pretreated sludge on hydrolysis and acidification, an experiment was carried out in 3 serum bottles A, B, C with a working volume of 250 mL respectively. The experiment lasted for 3 days. In bottle A, deflocculated- disperser pretreated sludge and seed sludge (Anaerobically digested sludge) was taken in the ratio 9:1. In bottle B, flocculated-disperser pretreated sludge and seed sludge was taken in the ratio 9:1. Similarly in bottle C, raw sludge and seed sludge was taken in the ratio 9:1. Heat treatment and BESA (2-bromoethanesulfonic acid) addition have been reported to efficiently get rid of methanogens from anaerobic fermentation system (Basu et al., 2005). For this reason the mixture was heated at 102 °C for 30 min and cooled down to room temperature. Subsequently the mixture added with BESA with a concentration 50 mM. All the bottles were capped with rubber stoppers and flushed with nitrogen gas to remove oxygen before the anaerobic digestion. The bottles were placed in a shaker at 120 rpm for 72 h at 35 °C. Samples were analysed at 0 h and after 72 h.

2.5. Anaerobic biodegradability assay

A biochemical methane potential (BMP) assay was performed to evaluate the potential for biogas recovery from sludge after disperser pretreatment. A batch assay was performed at 35 °C in three reactors namely A, B, C to study the biogas production efficiency of deflocculated, flocculated and raw sludge respectively. Rumen bacteria from the digestive tract of cow was used as the inoculum. 50 mL of sludge samples (deflocculated, flocculated and raw) were mixed with 150 mL of inoculums (cow's rumen fluid) and fed into the reactors A, B and C of 300 mL capacity each respectively. Reactor C fed with the raw sludge sample was run as a control. After the addition of substrates and the inoculum, the head space above the liquid in the reactors were purged with 30% CO_2 and 70% N_2 gas to eliminate the oxygen from the system to ensure complete anaerobic conditions. The gas mixture was introduced into the reactors at the rate of 1 L min^{-1} for 5 min. Then, the reactors were sealed with a rubber septum to make it air tight and were wrapped around with aluminium foil to provide a dark environment ideal for microbial growth within the reactors. Mixing was performed daily using an orbital shaker (150–200 rpm). The biogas was measured by inserting a needle into the septum. Gas accumulation produced during the incubation was collected using a syringe. The syringe piston was pushed up due to the increase of pressure inside the bottle when the gas was produced and the displaced volume was recorded. Batch reactors were operated with a residence time of 35 days. The methane content in the biogas was measured using a gas chromatograph. The modified Gompertz equation was used

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