Bioresource Technology 144 (2013) 121–127

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Decentralized application of anaerobic digesters in small poultry farms: Performance analysis of high rate self mixed anaerobic digester and conventional fixed dome anaerobic digester

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HIGHLIGHTS

- Self-mixed anaerobic digester (SMAD) is high rate digester.
- SMAD suitable for biomethanation of poultry litter and decentralized application.
- SMAD performance was better than conventional fixed dome anaerobic digester.
- Methane yield was as high as 0.15 m^3/(kg VS fed) at HRT of only 24 days in SMAD.
- SMAD would be remunerative for the farmer in terms of biogas and bio-manure.

ARTICLE INFO

Article history:
Received 19 April 2013
Received in revised form 19 June 2013
Accepted 20 June 2013
Available online 28 June 2013

Keywords:
Poultry litter
Biomethanation
Biogas
CFDAD
SMAD

ABSTRACT

Biomethanation of poultry litter was studied in conventional fixed dome anaerobic digester (CFDAD) and high rate self mixed anaerobic digester (SMAD) for possible decentralized application in poultry farms generating litter in the range of 500 kg/day. The performance of CFDAD and SMAD was compared. The study revealed that optimized hydraulic residence time (HRT), volatile solids (VS) loading rate, VS reduction, methane yield was 24 days, 4.0 kg VS/m^3/day, 64%, 0.15 m^3/(kg VS fed) and 40 days, 2.15 kg/m^3/day, 42%, 0.083 m^3/(kg VS fed) for SMAD and CFDAD, respectively. Better results with SMAD could be attributed to specific design features and intermittent mixing of the digester contents due to self-mixing mechanism. Preliminary cost estimates revealed that installation of SMAD would be remunerative for the farmer in terms of biogas and bio-manure.

1. Introduction

Intensification of poultry farming in developing countries is taking place rapidly as the poultry meat and egg are affordable food products. Operations are mechanized in large commercial farms and management of poultry waste could be addressed with a variety of available options (http://www.poultryhub.org/production/husbandry-management/housing-environment/waste-management/). However, poultry waste management in small and medium farms are a matter of great concern (http://www.fao.org/ag/againfo/home/events/bangkok2007/docs/part2/2_2.pdf) especially in developing countries (http://www.fao.org/docrep/013/al7 15e/al715e00.pdf). Poultry litter is highly biodegradable and hence anaerobic method of disposal is the most preferred option (Gangagni Rao et al., 2008a,b, 2011, 2012; Sakar et al., 2009; Kelleher et al., 2002; Salminen and Rintala, 2002a; Keri et al., 2008; Xiaojiao et al., 2012; Singh et al., 2010). Studies were reported on conventional batch type digesters for production of biogas from poultry litter (Bujoczek et al., 2000; Callaghan et al., 1999; Fatma Abouelenien et al., 2009; Francesco Fantozzi and Cinzia Buratti, 2009; Hill and Bolte, 2000; Nuri et al., 2001). However, such batch type conventional plants without mixing are not suitable for the treatment of poultry litter on long term basis due to scum formation at the top and choking at the bottom of the digester (Vilis Dubrovskis et al., 2008; Sakar et al., 2009; Yadvika et al., 2004; Gangagni Rao et al., 2008b). In general high rate biomethanation systems are multi stage configurations (Gangagni Rao et al., 2011; Nuri et al., 2001 Sakar et al., 2009; Kelleher et al., 2002; Salminen and Rintala, 2002a; Keri et al., 2008) and hence its applicability for treating smaller quantities of organic waste in the order of 500 kg are limited. In order to treat poultry litter in the range of 100–500 kg per day, a single stage batch type anaerobic digester with novel mixing arrange-

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0960-8524/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2013.06.076

ment (Gangagni Rao et al., 2008b, 2011; Karim et al. 2005a Karim et al., 2005b; Yadvika et al., 2004; Prasad et al., 2008) would be ideal to overcome the difficulties associated with conventional digester as well as to get the performance similar to high rate anaerobic digester. In the present work, high rate biomethanation of poultry litter was studied in self-mixed anaerobic digester (SMAD) (Gangagni Rao et al., 2008b, 2011) and its performance was also compared with conventional fixed dome anaerobic digester (CFDAD) of similar capacity.

2. Methods

2.1. Poultry litter

Poultry litter (deep litter) was collected from a poultry farm near Hyderabad, Andhra Pradesh, India under sun-dried conditions. The litter was brought to the laboratory and stored under dry conditions. Poultry litter slurry was prepared from the stored poultry litter and fed to the digester everyday as per requirement.

2.2. Experimental set up

The experimental set up consisted of 200 L feed slurry preparation tank (FPT), self mixing anaerobic digester (SMAD), conventional fixed dome anaerobic digester (CFDAD), gravity filter (GF) and floating dome type biogas holder (BH). All the units were made of high density polyethylene (HDPE). The FPT was circular in shape with conical bottom and a damper to remove grits. It was also fitted with aeration and overflow arrangement to discharge the homogenized slurry to SMAD and CFDAD separately. SMAD had two compartments viz; bottom and upper chamber. Both the chambers of SMAD were hydraulically connected with central draft pipe (Gangagni Rao et al., 2008b). Fresh slurry was fed to the bottom chamber of the digester and pressure developed in the bottom chamber due to the production of biogas was utilized for mixing the slurry. Slurry travels up and down in both the chambers of digester through draft tube due to the differential pressure in both the chambers. Movement of the slurry across the two chambers occurs by automatic opening of the valve as per the set pressure. During this movement, the slurry created vibrant mixing whenever it falls into the bottom chamber. Thus the slurry in the bottom chamber becomes homogeneous and well mixed. Mixing of the digester contents intermittently is one of the important criteria for improving the performance of anaerobic digester. Both SMAD and CFDAD having capacities of 2 m^3 each were connected in parallel to the FPT and GF. SMAD and CFDAD were fitted with heating coil having on/off control to maintain the temperature at 37 ± 1 °C. Slurry temperature at the outlet of the digesters was measured regularly with a thermometer and it was found to be always in the range of 36–38 °C. The gas produced was measured using a wet gas flow meter and stored in BH. The volume of the BH was around 200 L. Solids were separated from the digested slurry from both the digesters with GF having stainless steel (SS) wire mesh. Schematic flow diagram of CFDAD and SMAD is shown in Fig. 1.

2.3. Inoculum

SMAD and CFDAD were seeded with active methanogenic sludge from multi stage high rate biomethanation plant that was reported previously (Gangagni Rao et al., 2011). The volatile suspended solids (VSS) of the seed sludge were 28.33 g/L and the methanogenic activity was 0.32 g CH_4-COD/g VSS/day. SMAD and CFDAD were seeded with 50% by volume of inoculum.

2.4. Analytical methods

Poultry litter was characterized for pH, total solids (TS), volatile solids (VS), fixed solids (FS), nitrogen (N) and phosphorus (P) initially. During the course of the experiments characteristics of poultry litter slurry were determined (Inlet and outlet from SMAD and CFDAD) for pH, TS & VS daily or weekly as per requirement. The characteristics of the poultry litter viz. pH, TS, VS, N and P were determined as per standard methods (APHA, 1998). The volume of the biogas produced was measured and composition was estimated by using Orsat apparatus (BSI, 1971). Analysis of each parameter was carried out in triplicate and the variation was within ±1.0% and the variation was shown while presenting the data.

All the chemicals used for analysis during the experiments were of AR grade.

2.5. Experimental procedure and operation

Poultry litter slurry (10–12% TS) was soaked in the FPT for one day, subsequently mixed with air for few minutes and allowed to settle. The homogenized slurry was charged to the SMAD and CFDAD simultaneously and allowed to digest under anaerobic conditions. The settled grit, sand and shells from the feed tank were separated and sun dried. Solids in the discharge from SMAD and CFDAD were separated using GF. Solids from GF were sun dried

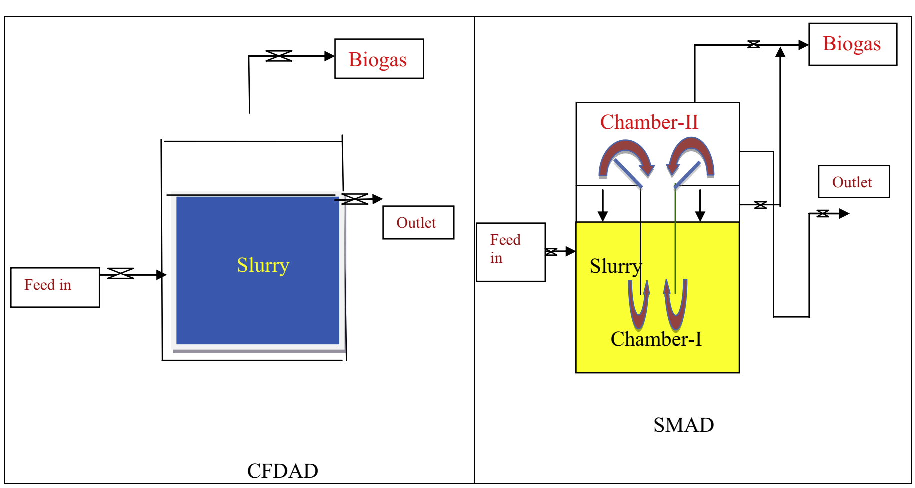

Fig. 1. Schemtic flow diagram of CFDAD and SMAD.